US009107177B2

(12) **United States Patent**
Mizusawa

(10) **Patent No.: US 9,107,177 B2**
(45) **Date of Patent: Aug. 11, 2015**

(54) **WIRELESS BASE STATION, TRANSMISSION POWER CONTROL METHOD AND COMPUTER PROGRAM**

(75) Inventor: **Nishiki Mizusawa**, Kanagawa (JP)

(73) Assignee: **Sony Corporation**, Tokyo (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 350 days.

(21) Appl. No.: **13/552,848**

(22) Filed: **Jul. 19, 2012**

(65) **Prior Publication Data**

US 2013/0040688 A1 Feb. 14, 2013

(30) **Foreign Application Priority Data**

Aug. 8, 2011 (JP) 2011-172927

(51) **Int. Cl.**

H04B 7/00	(2006.01)
H04W 52/36	(2009.01)
H04W 52/14	(2009.01)
H04W 52/24	(2009.01)
H04W 52/38	(2009.01)

(52) **U.S. Cl.**

CPC ***H04W 52/367*** (2013.01); *H04W 52/143* (2013.01); *H04W 52/245* (2013.01); *H04W 52/362* (2013.01); *H04W 52/38* (2013.01)

(58) **Field of Classification Search**

CPC . H04W 52/00; H04W 52/143; H04W 52/245; H04W 52/38; H04W 52/362; H04W 52/367

USPC 455/69, 522; 370/318

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

8,208,363	B2 *	6/2012	Kishiyama et al.	370/204
2009/0264155	A1 *	10/2009	Nakayama et al.	455/561
2010/0054237	A1 *	3/2010	Han et al.	370/350
2010/0111022	A1 *	5/2010	Chang et al.	370/329
2011/0003597	A1 *	1/2011	Budic et al.	455/450
2011/0158196	A1 *	6/2011	Power et al.	370/329

FOREIGN PATENT DOCUMENTS

JP	2010-283756 A	12/2010	

* cited by examiner

Primary Examiner — Raymond Dean

(74) *Attorney, Agent, or Firm* — Sony Corporation

(57) **ABSTRACT**

Provided is a wireless base station including a power measurement unit for measuring a power of a reference signal for synchronization at a downlink adjacent frequency; a base station type acquisition unit for acquiring a type of a base station that transmits the signal at the downlink adjacent frequency; and a power setting unit for setting a maximum transmission power based on a measurement value of the power measured by the power measurement unit and the type of the base station acquired by the base station type acquisition unit.

14 Claims, 15 Drawing Sheets

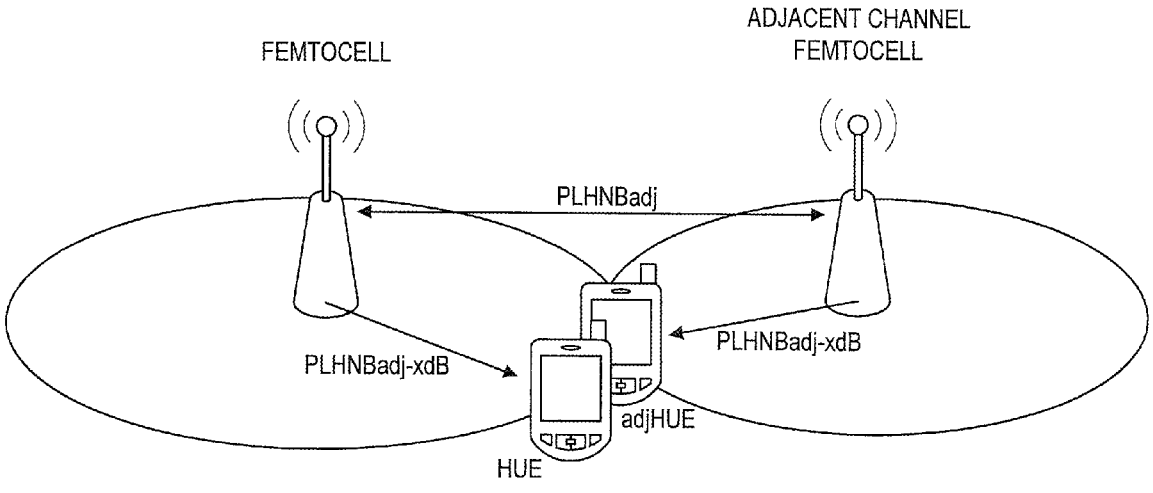


FIG. 1

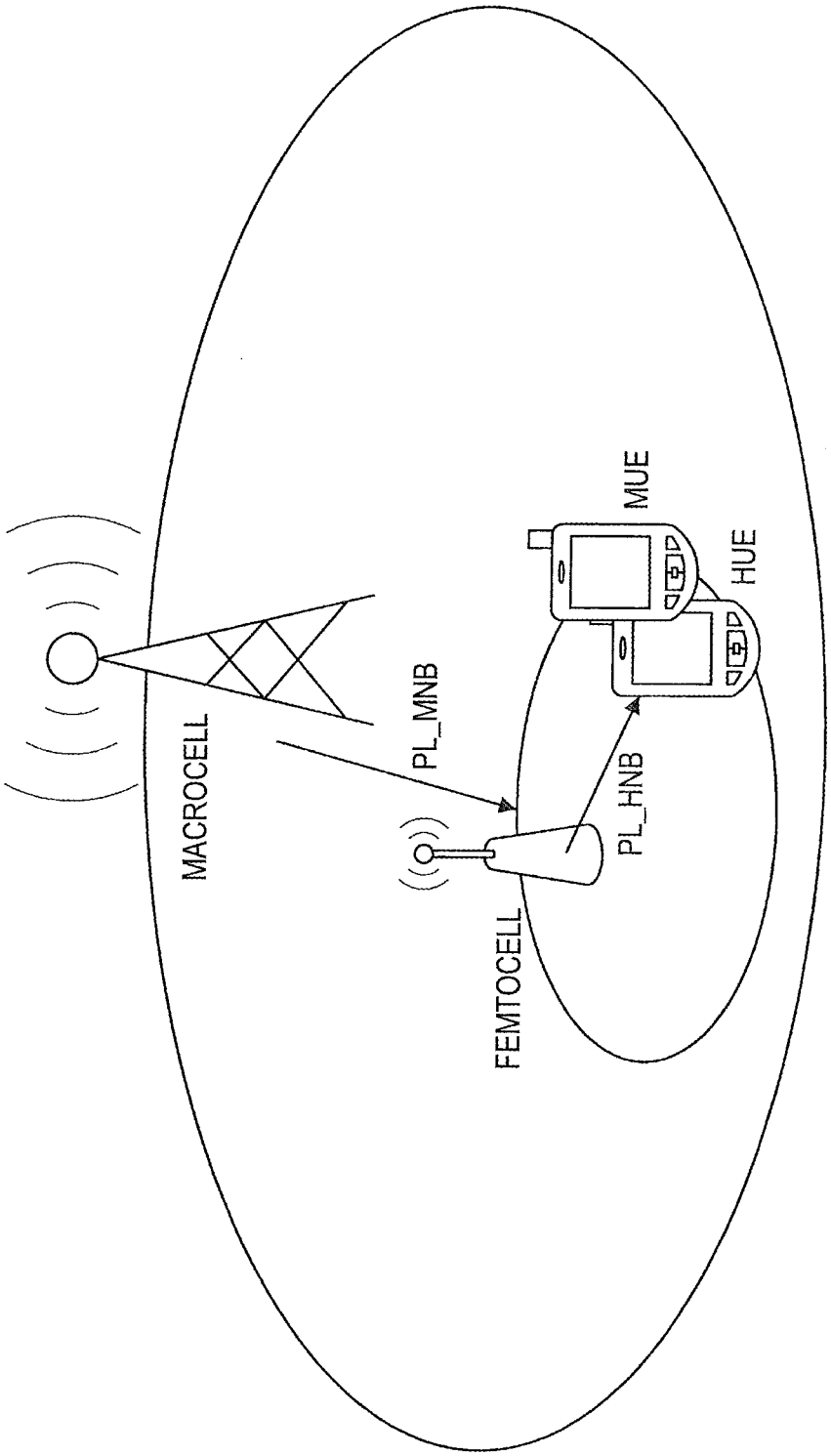


FIG. 2

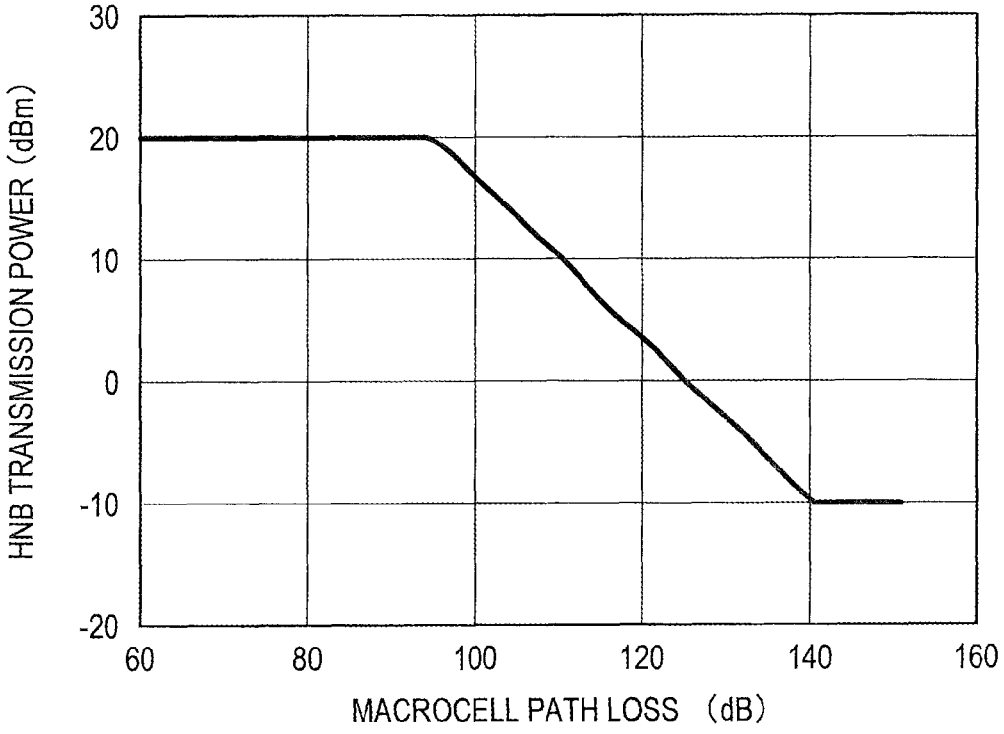

30
20
10
0
-10
-20
HNB TRANSMISSION POWER (dBm)
60
80
100
120
140
160
MACROCELL PATH LOSS (dB)

FIG. 3

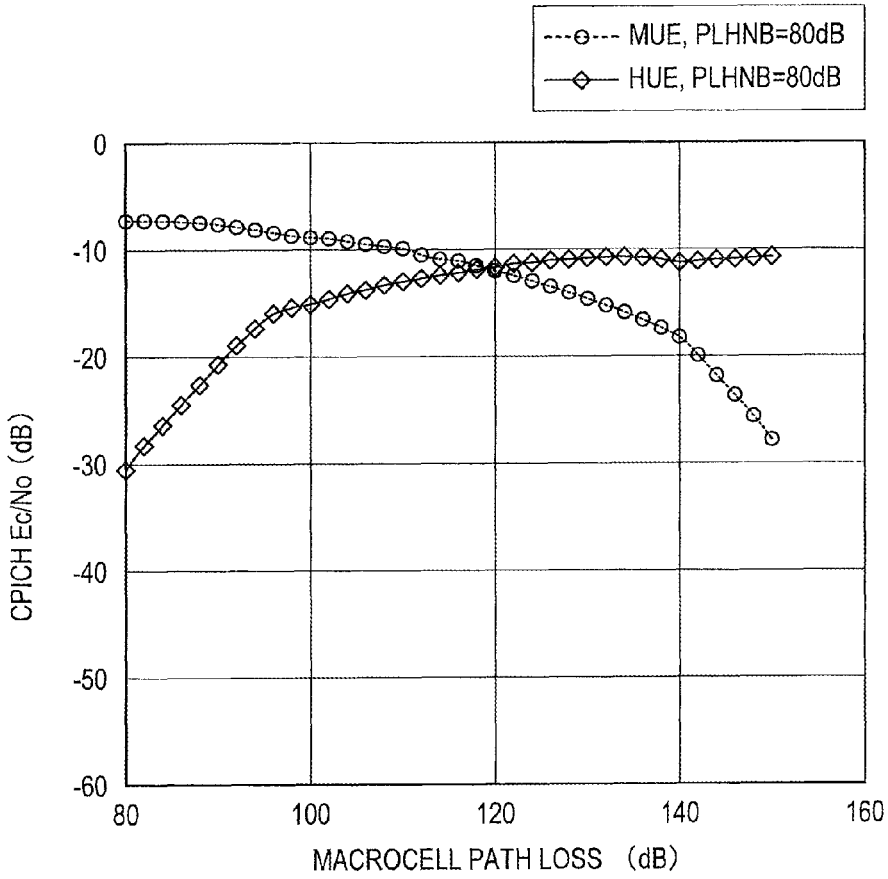

MUE, PLHNB=80dB
HUE, PLHNB=80dB
0
-10
-20
-30
-40
-50
-60
CPICH Ec/No (dB)
80
100
120
140
160
MACROCELL PATH LOSS (dB)

FIG. 4

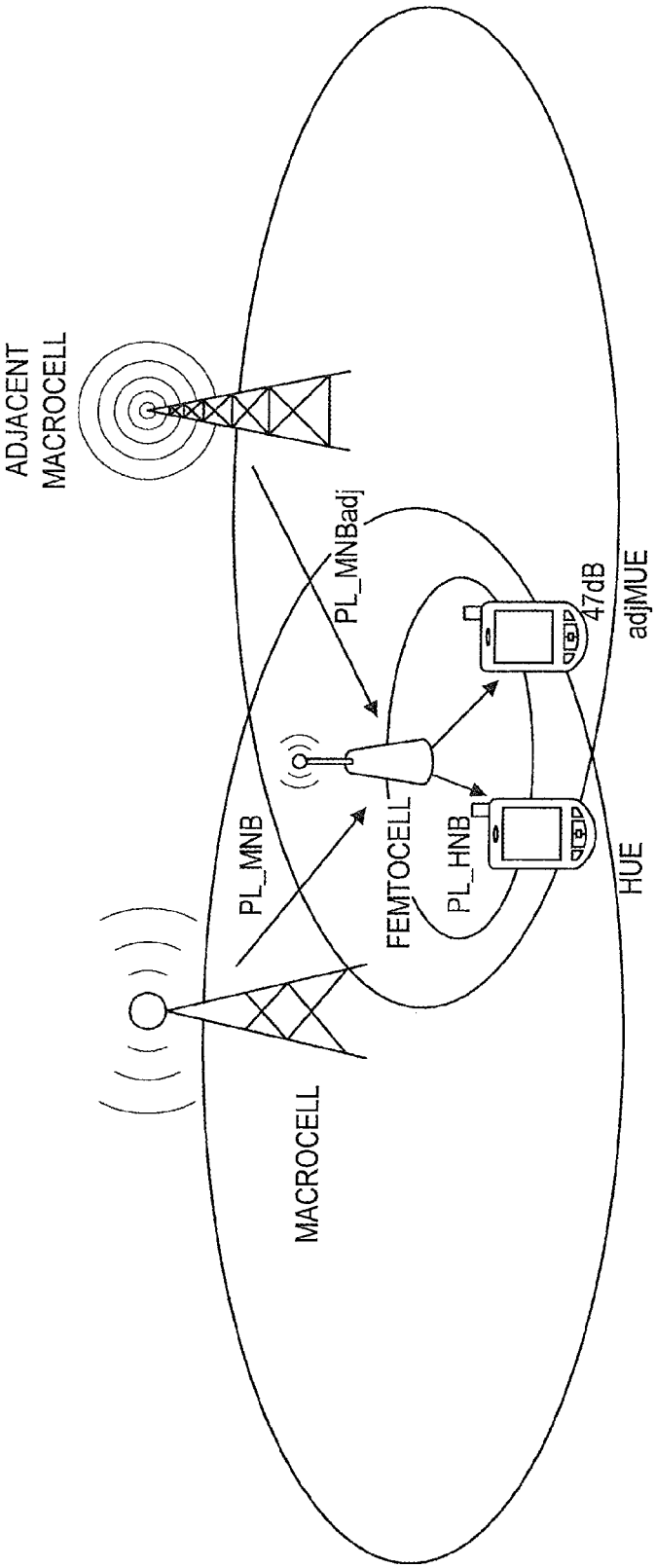

ADJACENT MACROCELL
PL_MNBadj
47dB
adjMUE
PL_MNB
FEMTOCELL
PL_HNB
HUE
MACROCELL

FIG. 5

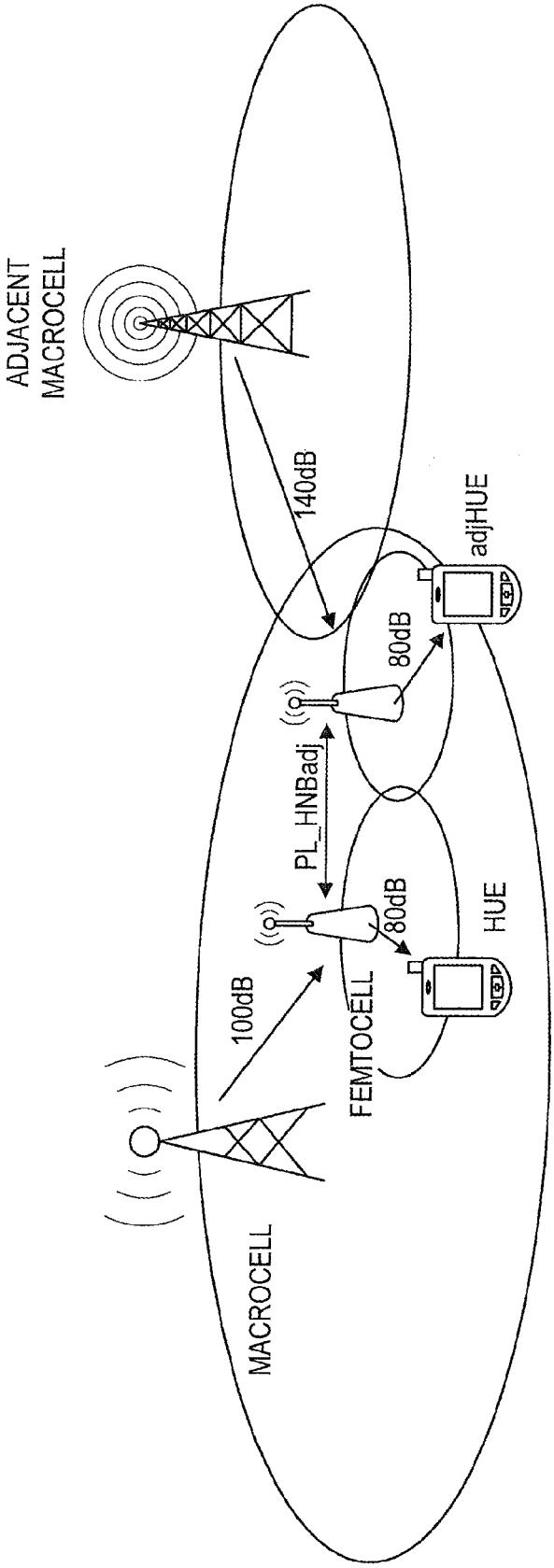

ADJACENT MACROCELL
140dB
adjHUE
80dB
PL_HNBadj
80dB
HUE
100dB
FEMTOCELL
MACROCELL

FIG. 6

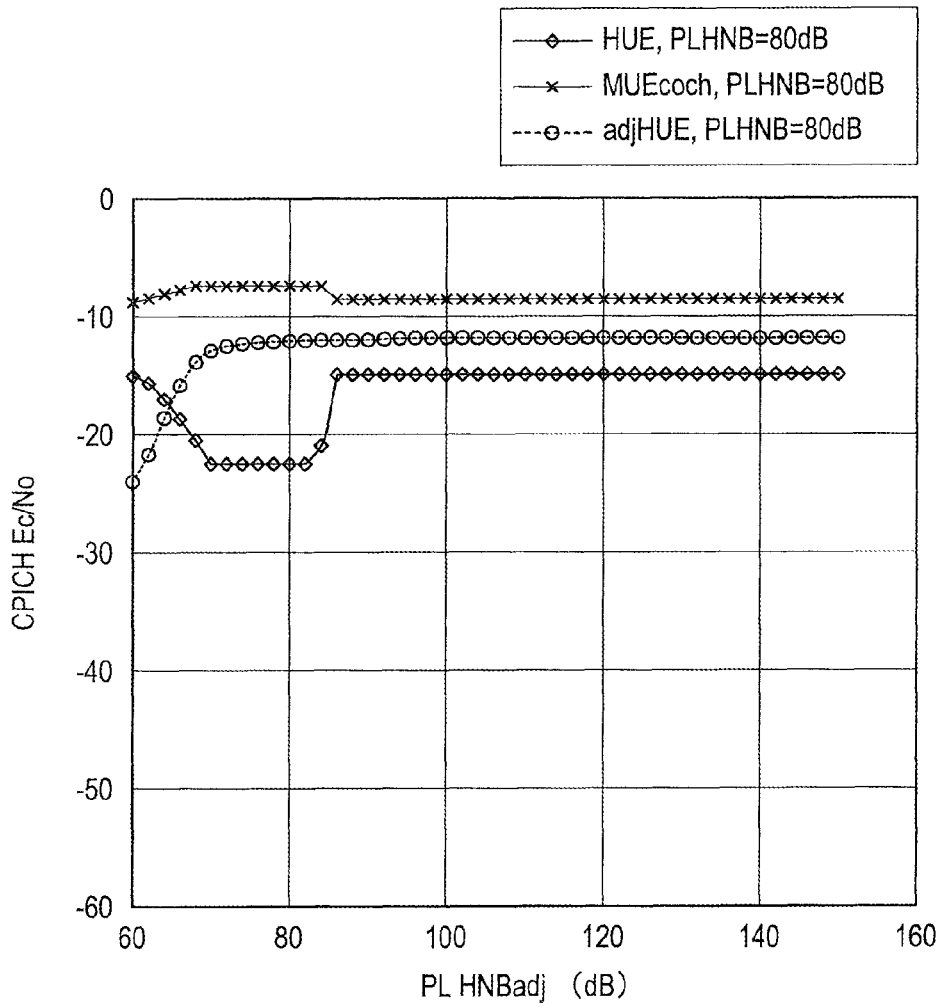

HUE, PLHNB=80dB
MUEcoch, PLHNB=80dB
adjHUE, PLHNB=80dB
0
-10
-20
-30
-40
-50
-60
CPICH Ec/No
60
80
100
120
140
160
PL HNBadj (dB)

FIG. 7

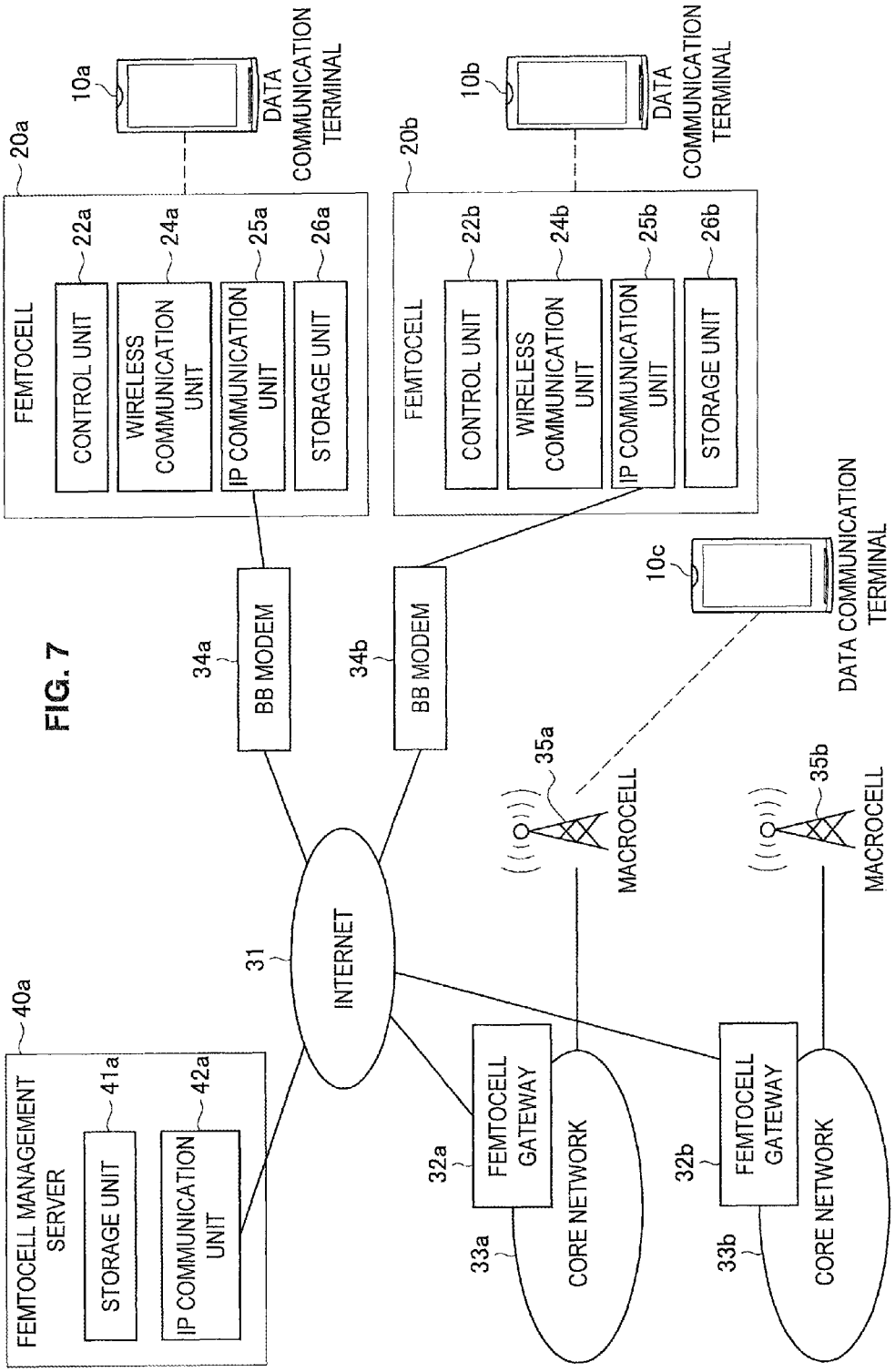

10a
DATA COMMUNICATION TERMINAL
10b
DATA COMMUNICATION TERMINAL
10c
DATA COMMUNICATION TERMINAL
20a
FEMTOCELL
CONTROL UNIT
22a
WIRELESS COMMUNICATION UNIT
24a
IP COMMUNICATION UNIT
25a
STORAGE UNIT
26a
20b
FEMTOCELL
CONTROL UNIT
22b
WIRELESS COMMUNICATION UNIT
24b
IP COMMUNICATION UNIT
25b
STORAGE UNIT
26b
34a
BB MODEM
34b
BB MODEM
31
INTERNET
35a
MACROCELL
35b
MACROCELL
32a
FEMTOCELL GATEWAY
32b
FEMTOCELL GATEWAY
33a
CORE NETWORK
33b
CORE NETWORK
40a
FEMTOCELL MANAGEMENT SERVER
STORAGE UNIT
41a
IP COMMUNICATION UNIT
42a

FIG. 8

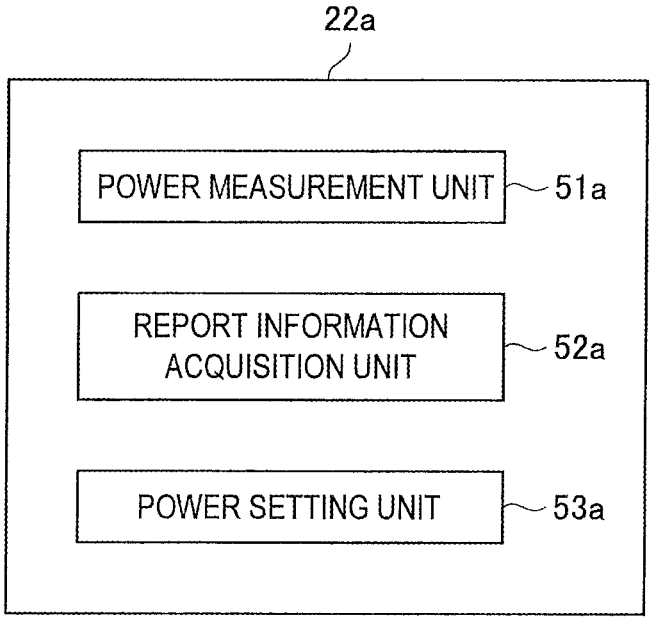

22a
POWER MEASUREMENT UNIT
51a
REPORT INFORMATION ACQUISITION UNIT
52a
POWER SETTING UNIT
53a

FIG. 9A

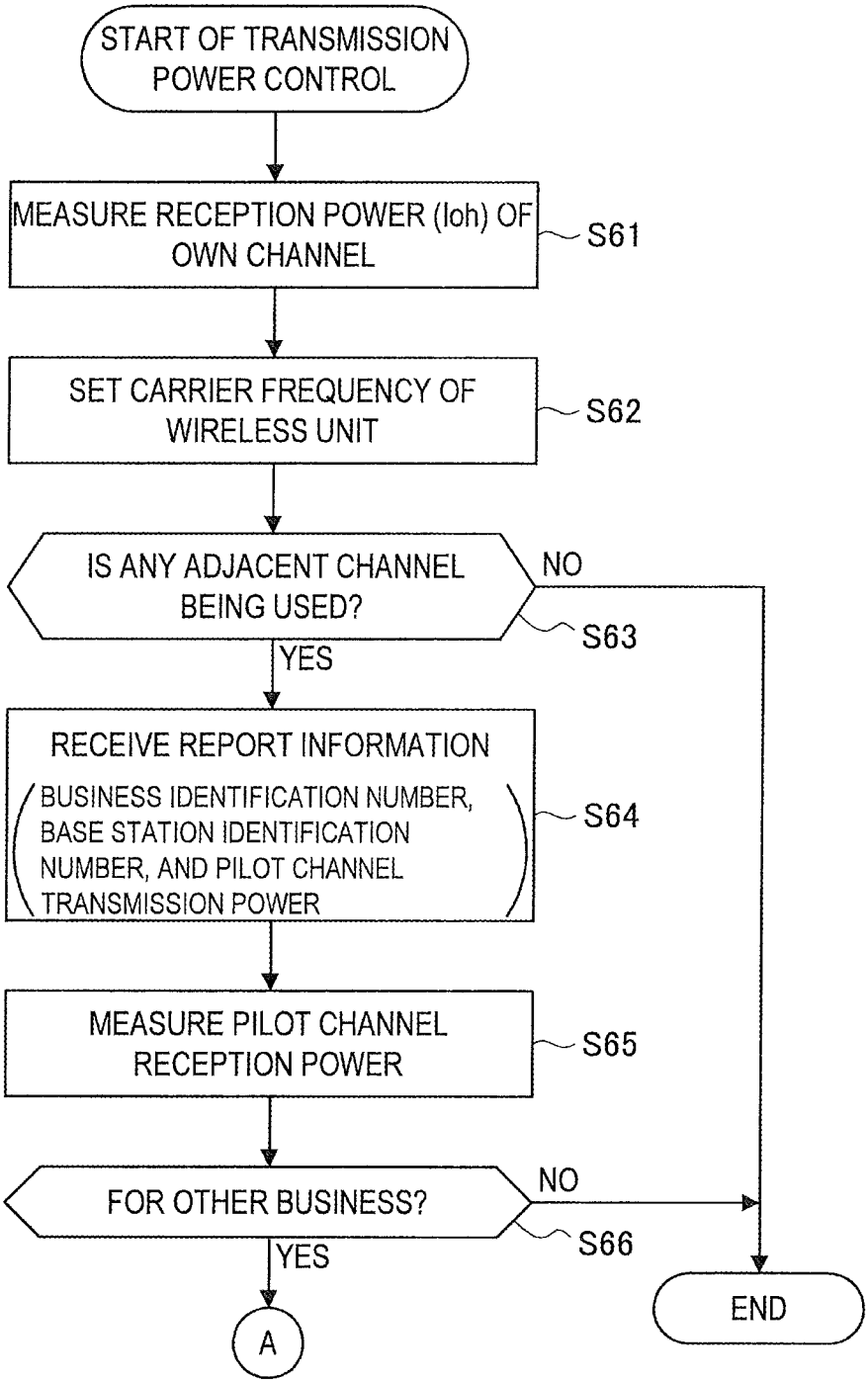

START OF TRANSMISSION POWER CONTROL
MEASURE RECEPTION POWER (Ioh) OF OWN CHANNEL
S61
SET CARRIER FREQUENCY OF WIRELESS UNIT
S62
IS ANY ADJACENT CHANNEL BEING USED?
NO
S63
YES
RECEIVE REPORT INFORMATION
(BUSINESS IDENTIFICATION NUMBER, BASE STATION IDENTIFICATION NUMBER, AND PILOT CHANNEL TRANSMISSION POWER)
S64
MEASURE PILOT CHANNEL RECEPTION POWER
S65
FOR OTHER BUSINESS?
NO
S66
YES
A
END

FIG. 9B

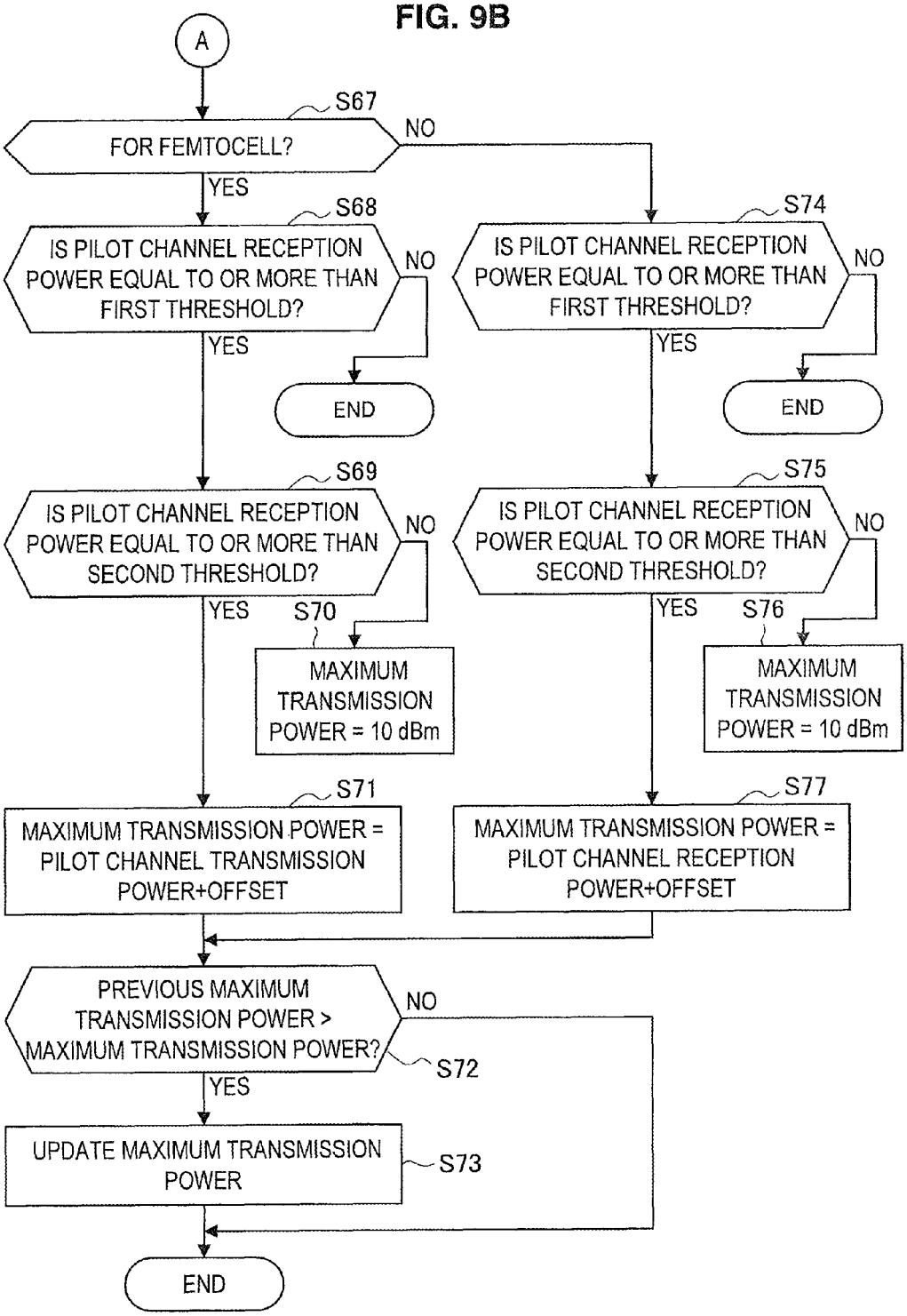

A
S67
FOR FEMTOCELL?
NO
YES
S68
IS PILOT CHANNEL RECEPTION POWER EQUAL TO OR MORE THAN FIRST THRESHOLD?
NO
YES
END
S74
IS PILOT CHANNEL RECEPTION POWER EQUAL TO OR MORE THAN FIRST THRESHOLD?
NO
YES
END
S69
IS PILOT CHANNEL RECEPTION POWER EQUAL TO OR MORE THAN SECOND THRESHOLD?
NO
YES
S70
MAXIMUM TRANSMISSION POWER = 10 dBm
S75
IS PILOT CHANNEL RECEPTION POWER EQUAL TO OR MORE THAN SECOND THRESHOLD?
NO
YES
S76
MAXIMUM TRANSMISSION POWER = 10 dBm
S71
MAXIMUM TRANSMISSION POWER = PILOT CHANNEL TRANSMISSION POWER+OFFSET
S77
MAXIMUM TRANSMISSION POWER = PILOT CHANNEL RECEPTION POWER+OFFSET
PREVIOUS MAXIMUM TRANSMISSION POWER > MAXIMUM TRANSMISSION POWER?
NO
S72
YES
UPDATE MAXIMUM TRANSMISSION POWER
S73
END

FIG. 10

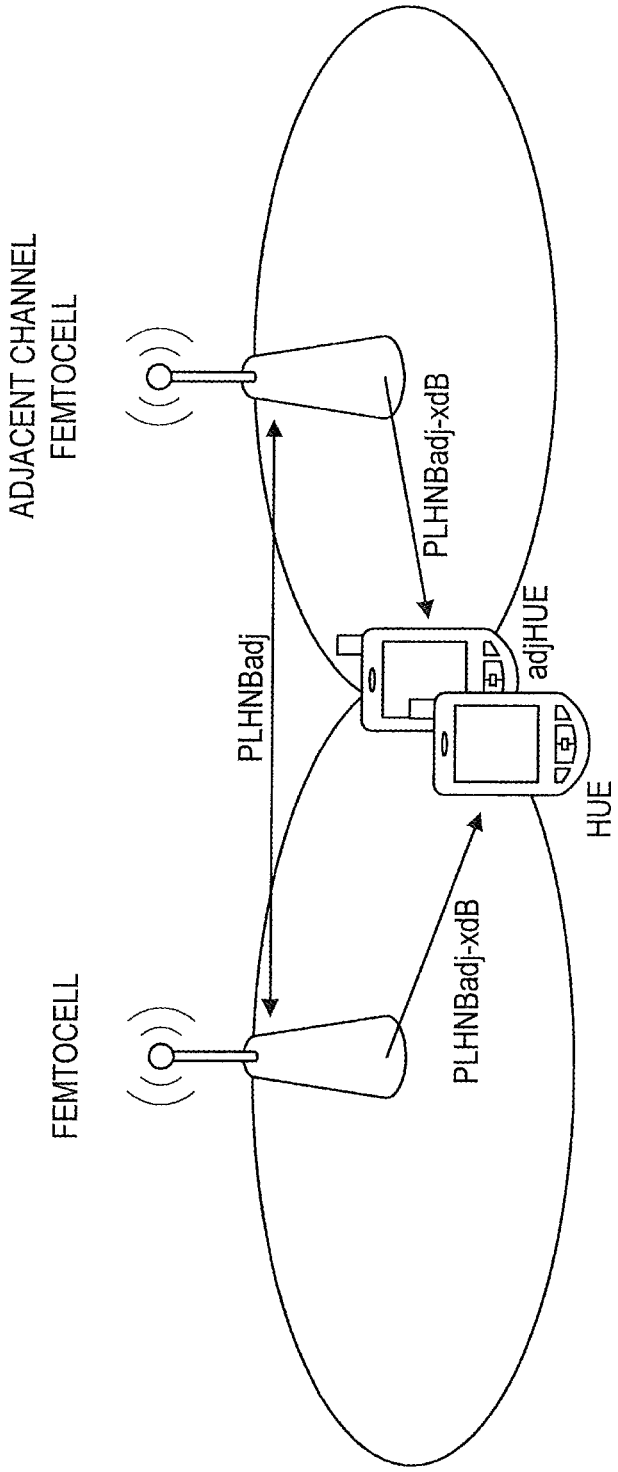

ADJACENT CHANNEL
FEMTOCELL
PLHNBadj-xdB
adjHUE
PLHNBadj
HUE
FEMTOCELL
PLHNBadj-xdB

FIG. 11

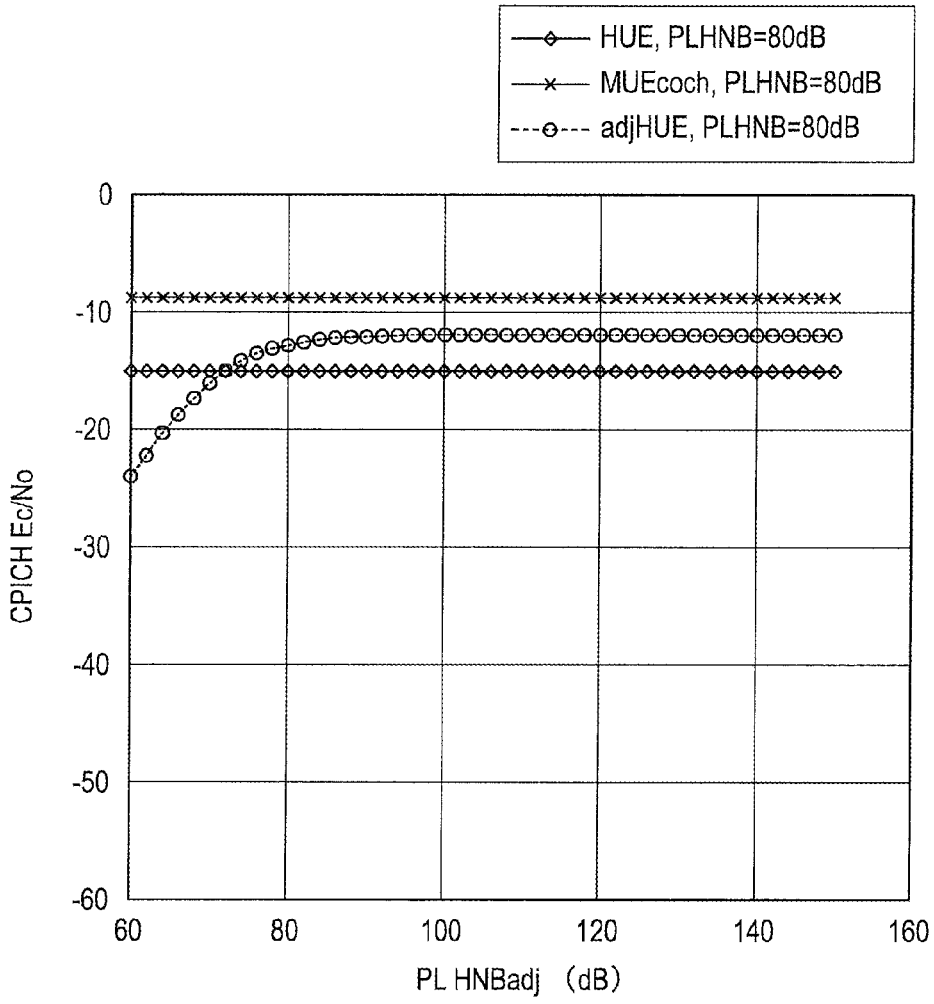

HUE, PLHNB=80dB
MUEcoch, PLHNB=80dB
adjHUE, PLHNB=80dB
0
-10
-20
-30
-40
-50
-60
CPICH Ec/No
60
80
100
120
140
160
PL HNBadj (dB)

FIG. 12

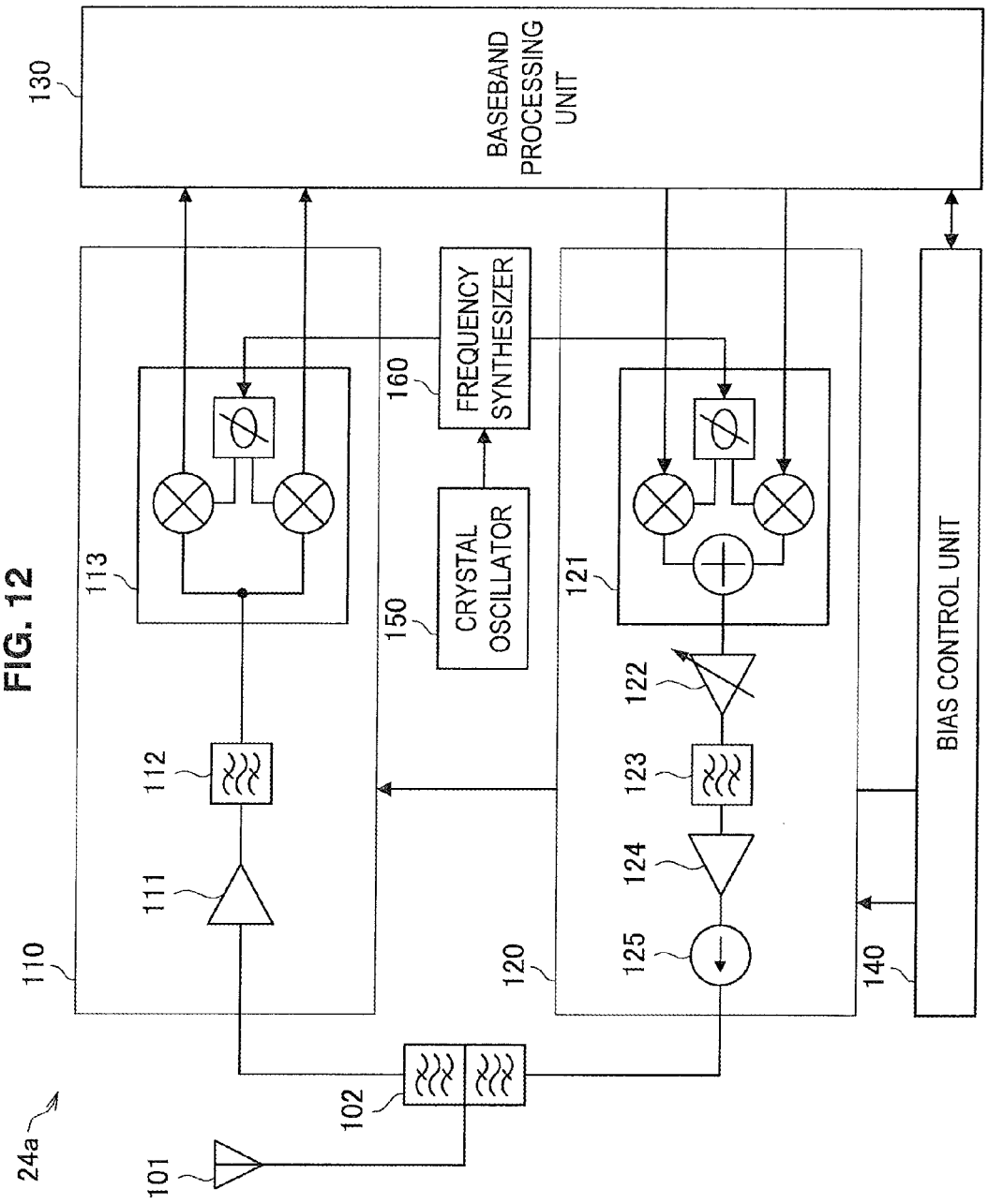

130
BASEBAND PROCESSING UNIT
160
FREQUENCY SYNTHESIZER
150
CRYSTAL OSCILLATOR
BIAS CONTROL UNIT
140
113
112
111
110
121
122
123
124
125
120
102
101
24a

FIG. 13

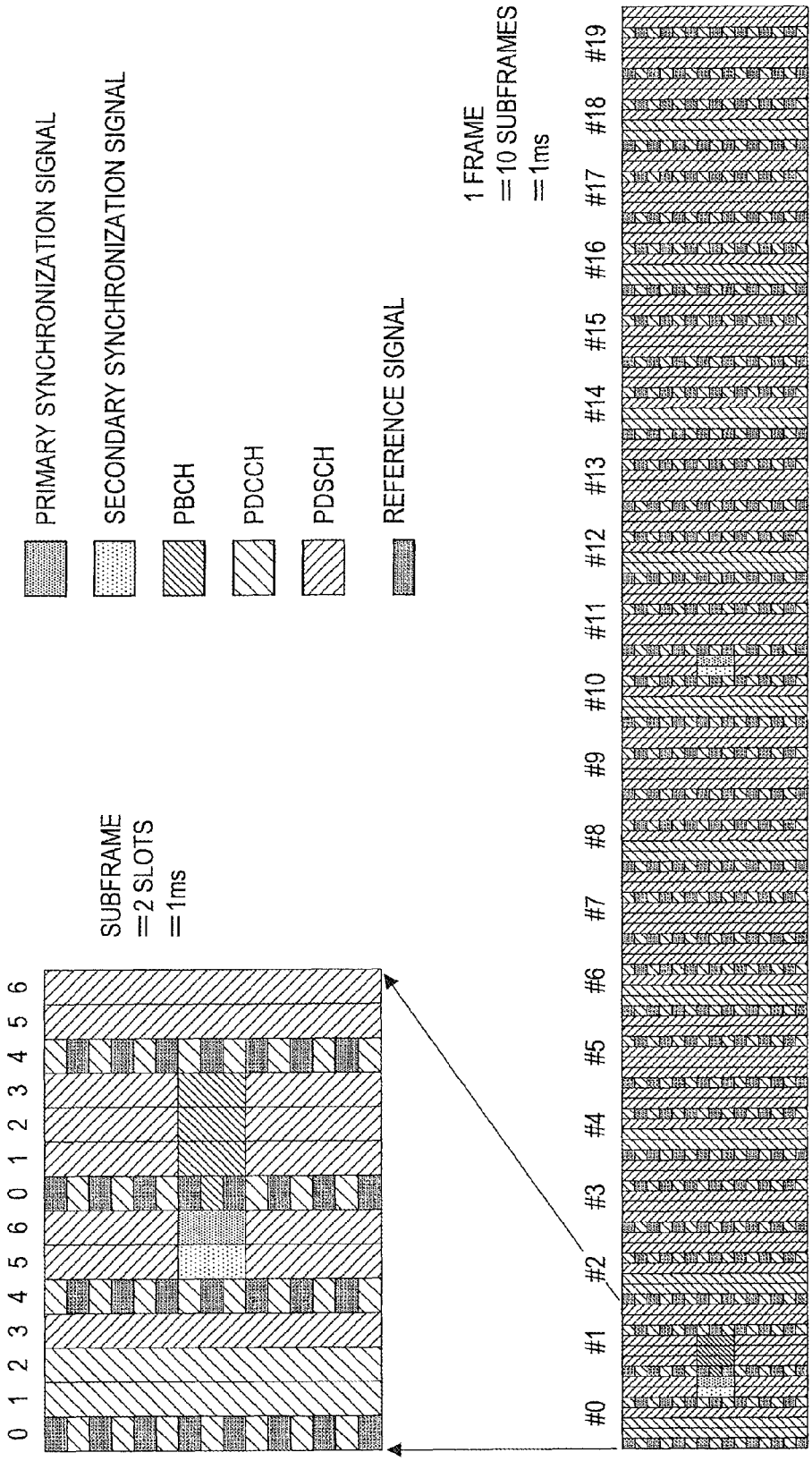
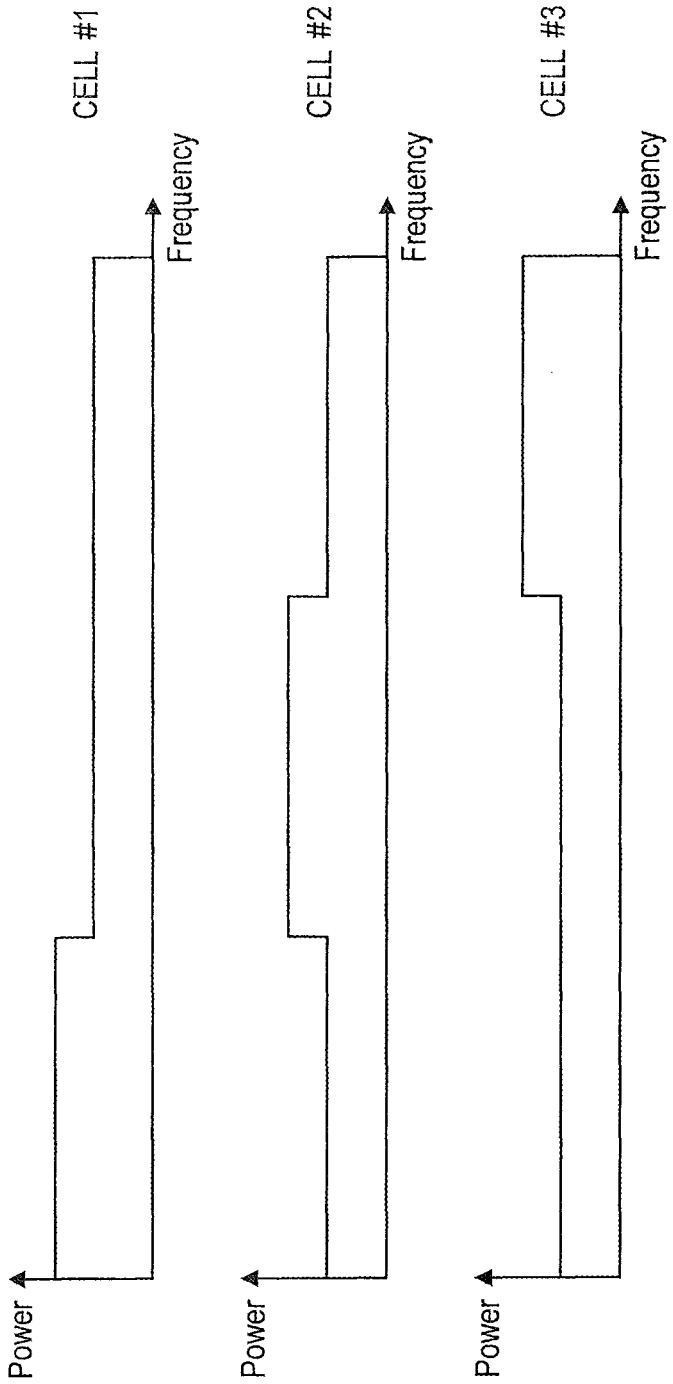

PRIMARY SYNCHRONIZATION SIGNAL
SECONDARY SYNCHRONIZATION SIGNAL
PBCH
PDCCH
PDSCH
REFERENCE SIGNAL
1 FRAME
=10 SUBFRAMES
=1ms
SUBFRAME
=2 SLOTS
=1ms
0 1 2 3 4 5 6 0 1 2 3 4 5 6
#0 #1 #2 #3 #4 #5 #6 #7 #8 #9 #10 #11 #12 #13 #14 #15 #16 #17 #18 #19

FIG. 14


CELL #1
Frequency
Power
CELL #2
Frequency
Power
CELL #3
Frequency
Power

WIRELESS BASE STATION, TRANSMISSION POWER CONTROL METHOD AND COMPUTER PROGRAM

BACKGROUND

The present disclosure relates to a wireless base station, a transmission power control method, and a computer program.

Data communication traffic is rapidly increasing with the spread of data communication terminals of a UMTS (Universal Mobile Telecommunications System) scheme, an LTE (Long Term Evolution) scheme, or the like. In particular, a traffic solution for the proportionally large volume of indoor data communication is urgently necessary.

There is a low-power base station for indoor use (a femtocell) connected to the Internet or an operator's core network via a broadband line (hereinafter, a BB line), such as ADSL (Asymmetric Digital Subscriber Line), FTTH (Fiber To The Home) or CATV. Since the femtocell can connect between a data communication terminal and the Internet without going through a core network, the femtocell is expected as a solution to the rapidly increasing traffic described above.

Further, a femtocell is installed in a home or an office by a user and can limit users (terminals) that can use the femtocell. The femtocell performs near-field communication with a data communication terminal in a relatively small service area (coverage). Accordingly, the femtocell provides a communication environment with good communication quality and high throughput.

As a low-power base station, in addition to the femtocell, there is a picocell that does not limit users that can use the picocell. The picocell provides a communication environment with good communication quality and high throughput and is expected as a solution to traffic toward a core network, similar to the femtocell. Technology for controlling a femtocell has also been disclosed.

[Patent Literature 1] Japanese Patent Application Laid-Open No. 2010-283756

SUMMARY

In technology for determining a maximum transmission power of a femtocell in a related art, a terminal serviced from a wide-area base station (a macrocell) of an adjacent frequency channel (a macrocell terminal) can be protected, but if a femtocell of an adjacent frequency channel is installed in the vicinity of the femtocell, a power of the femtocell is unnecessarily limited. This degrades communication quality of a terminal serviced from the femtocell (a femtocell terminal).

The present disclosure has been made in view of these problems and an object of the present disclosure is to provide a wireless base station, a transmission power control method, and a computer program that are novel and enhanced and are capable of setting an appropriate maximum transmission power according to a type of adjacent base station.

According to an embodiment of the present disclosure, there is provided a wireless base station including: a power measurement unit for measuring a power of a reference signal for synchronization at a downlink adjacent frequency; a base station type acquisition unit for acquiring a type of a base station that transmits the signal at the downlink adjacent frequency; and a power setting unit for setting a maximum transmission power based on a measurement value of the power measured by the power measurement unit and the type of the base station acquired by the base station type acquisition unit.

According to another embodiment of the present disclosure, there is provided a transmission power control method including: measuring a power of a reference signal for synchronization at a downlink adjacent frequency; acquiring a type of a base station that transmits the signal at the downlink adjacent frequency; and setting a maximum transmission power based on a measurement value of the power measured in the power measurement step and the type of the base station acquired in the base station type acquisition step.

According to another embodiment of the present disclosure, there is provided a computer program for causing a computer to execute: measuring a power of a reference signal for synchronization at a downlink adjacent frequency; acquiring a type of a base station that transmits the signal at the downlink adjacent frequency; and setting a maximum transmission power based on a measurement value of the power measured in the power measurement step and the type of the base station acquired in the base station type acquisition step.

As described above, according to the present disclosure, it is possible to provide a wireless base station, a transmission power control method, and a computer program that are novel and enhanced and are capable of setting an appropriate maximum transmission power according to a type of adjacent base station.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is an illustrative diagram showing an arrangement example of a macrocell and a femtocell;

FIG. **2** is an illustrative diagram showing an example of a method of controlling a maximum transmission power of a femtocell according to a path loss between a macrocell and the femtocell;

FIG. **3** is an illustrative diagram showing signal-to-noise power ratios of a macrocell terminal and a femtocell terminal;

FIG. **4** is an illustrative diagram showing a state in which a service area of a femtocell is included in an area of a macrocell;

FIG. **5** is an illustrative diagram showing an arrangement example of a macrocell and a femtocell;

FIG. **6** is an illustrative diagram showing signal-to-noise power ratios of a macrocell terminal and a femtocell terminal;

FIG. **7** is an illustrative diagram showing an overall configuration of a data communication system according to an embodiment of the present disclosure;

FIG. **8** is an illustrative diagram showing a configuration of a control unit according to an embodiment of the present disclosure;

FIG. **9**A is a flow diagram showing an operation of the control unit according to an embodiment of the present disclosure;

FIG. **9**B is a flow diagram showing an operation of the control unit according to an embodiment of the present disclosure;

FIG. **10** is an illustrative diagram showing an arrangement example of a macrocell and a femtocell;

FIG. **11** is an illustrative diagram showing signal-to-noise power ratios of a macrocell terminal and a femtocell terminal after control by the control unit according to an embodiment of the present disclosure;

FIG. **12** is an illustrative diagram showing a configuration example of a wireless communication unit;

FIG. **13** is an illustrative diagram showing a structure of a downlink radio frame of an LTE scheme; and

FIG. **14** is an illustrative diagram showing an example of a relationship between a frequency and a transmission power when division into a plurality of frequency blocks is performed in an LTE scheme.

DETAILED DESCRIPTION OF THE EMBODIMENTS

Hereinafter, preferred embodiments of the present disclosure will be described in detail with reference to the appended drawings. Note that, in this specification and the appended drawings, structural elements that have substantially the same function and structure are denoted with the same reference numerals, and repeated explanation of these structural elements is omitted.

Further, a description will be given in the following order:

<1. Related Art and its Problems>
<2. Embodiment of the Present Disclosure>
[2-1. Overall Configuration of Data Communication System]
[2-2. Method Using Another Calculation Method when Adjacent Channel is for Femtocell]
[2-3. Method of Excluding Power from Adjacent Femtocell]
[2-4. Method of Setting Threshold and Offset Value According to Base Station Type]
[2-5. Method of Setting Plurality of Maximum Transmission Power Candidates]
<3. Conclusion>

1. Related Art and its Problem

First, a related art and its problems will be described in describing a preferred embodiment of the present disclosure in detail.

FIG. **1** is an illustrative diagram showing an arrangement example of a macrocell and a femtocell. The macrocell is a wireless base station capable of covering a very wide range. On the other hand, the femtocell is a wireless base station that covers a much narrower range than the macrocell.

A maximum transmission power of the wireless base station refers to an allowed value of a total power transmitted by the wireless base station in an allowed frequency band. For example, physical channels on a downlink that a wireless base station of a UMTS scheme transmits to a terminal include a dedicated physical data channel (DPDCH) for transmission of data for an individual user, a dedicated physical control channel (DPCCH) for transmission of control information for the individual user, a common pilot channel (CPICH) that is a time reference of channel estimation or another channel, a common control physical channel (CCPCH) for transmission of report information, a synchronization channel (SCH) used for a terminal to perform cell search and synchronization, and the like. A power of, for example, the dedicated physical data channel varies with the number of users serviced by the wireless base station, but a maximum transmission power indicates a maximum value allowed for a total power of all the channels.

The terminal performs, for example, synchronization establishment and channel estimation by receiving a reference signal for synchronization transmitted by the wireless base station, and performs data transmission and reception to and from the wireless base station. Accordingly, it is necessary to enable the terminal to receive the reference signal for synchronization with good reception quality in order to provide good communication quality. The reference signal for synchronization refers to, for example, a common pilot channel (CPICH) in a UMTS scheme and a cell-specific reference signal (CRS) that is one of downlink reference signals in an LTE scheme. The reference signal for synchronization is transmitted with a certain transmission power at a fixed power ratio to the maximum transmission power (e.g., the maximum transmission power −10 dB).

It is necessary for the wireless base station to suppress interference with another base station in order to secure its coverage and communication quality. Between base stations operated at the same frequency, interference is suppressed by separation based on a scrambling code and transmission power control, for example, in the UMTS scheme, and by radio resource (a sub-carrier frequency or resource block timing) separation and transmission power control, for example, in the LTE scheme. Between base stations operated at different frequencies, interference is suppressed by filter-based separation and transmission power control. For example, in the UMTS scheme, an adjacent channel rejection ratio of 33 dB can be obtained by a filter.

A wide-area base station (a macrocell) that provides coverage of a wide area and a large user capacity is a base station whose installation place and maximum transmission power are determined after detailed site survey has been carried out. Usually, the maximum transmission power of the wide-area base station is not changed unless there is a design change in a wireless network. On the other hand, the femtocell is a base station arbitrarily installed by a user. Since it is difficult for an operator to recognize, for example, an operation start time, it is necessary for the femtocell to have a function of autonomously setting radio parameters such as an optimal maximum transmission power. The radio parameters include a carrier frequency, a scrambling code, a base station ID, and the like, as well as the maximum transmission power, for example, in the case of the UMTS scheme.

For the femtocell to have a mechanism for limiting users (terminals) that can use the femtocell, interference is an important issue. In particular, avoidance of interference between a femtocell and a macrocell operated at the same frequency is absolutely necessary for the femtocell. A terminal serviced from the macrocell (a macrocell terminal), which is not authorized to access the femtocell, is not handed over to the femtocell even when a downlink signal from the femtocell becomes larger than a downlink signal from the macrocell due to the macrocell terminal being close to the femtocell. The downlink signal transmitted by the femtocell becomes an interference noise for the macrocell terminal. On the other hand, the downlink signal transmitted from the macrocell becomes an interference noise for a terminal serviced from the femtocell (a femtocell terminal).

Where the femtocell is installed, it is necessary to set, in the femtocell, radio parameters for avoiding an interference with a macrocell so that communication is not disabled by interference from the femtocell when the macrocell terminal is close to the femtocell. With respect to setting of the carrier frequency and the scrambling code among the above-described radio parameters in the UMTS scheme, for example, there is a method in which the femtocell, when starting up, accesses a femtocell management server and selects a carrier frequency and a scrambling code not to overlap a carrier frequency and a scrambling code used by a peripheral base station by referencing a carrier frequency list or a scrambling code list operated by the same operator.

On the other hand, with respect to the maximum transmission power among the above-described radio parameters, intensity of a radio wave transmitted by a peripheral base station can be measured by the femtocell and a maximum

transmission power of the femtocell can be set to suppress interference with the peripheral base station as much as possible.

For example, a guideline on a method of controlling a transmission power of a femtocell (Home Node B) of a UMTS scheme has been introduced in 3GPP TR 25.967. In this guideline, a method by which a femtocell measures power of a reference signal for synchronization (pilot channel) of a peripheral macrocell to determine a maximum transmission power of the femtocell so that a signal-to-noise power ratio (CPICH Ec/No) in both a femtocell terminal and a macrocell terminal located in the vicinity of a boundary of a service area of the femtocell is higher than a level necessary for reception is shown. In this guideline, a power measurement value of the pilot channel of the macrocell by the femtocell is used as a measurement value of a terminal. This is because a small service area of the femtocell is included in a wide area of the macrocell and a distance between the femtocell and the terminal is smaller than a distance between the macrocell and the femtocell, as shown in FIG. **1**.

FIG. **2** shows an example of a method of controlling a maximum transmission power of a femtocell according to a path loss between a macrocell and the femtocell when a range in which a propagation loss (a path loss) from the femtocell is 80 dB is a service area of the femtocell.

FIG. **3** shows a signal-to-noise power ratio (CPICH Ec/No) of a macrocell terminal and a femtocell terminal present in positions with a path loss of 80 dB from the femtocell when the maximum transmission power of the femtocell is set as shown in FIG. **2**. The path loss from the macrocell is assumed to be about 100 dB at a cell center and about 140 dB at a cell edge. It can be seen that a condition necessary for the macrocell terminal (CPICH Ec/No≥−18 dB) and a condition necessary for the femtocell terminal (CPICH Ec/No≥−15 dB) are nearly satisfied in a service area (a range of the path loss of 100 to 140 dB) of the macrocell. Thus, control of the transmission power of the femtocell based on the path loss between the macrocell and the femtocell may be used as a method of reducing interference from the femtocell, which operates with the same frequency as and a different scrambling code from the macrocell, to the macrocell terminal.

For example, a method of suppressing interference of a control channel between a femtocell (Home eNode B) and a macrocell of the LTE scheme by shifting, in time, radio frames of the femtocell and the macrocell, a method of suppressing interference of a data channel by dividing a sub-carrier in a used frequency band between a femtocell and a macrocell and using the sub-carrier not to overlap, or the like has been introduced in the 3GPP TR 36.921.

In addition, a base station detecting interference may send a message indicating radio resources where the interference occurs to a base station causing such interference, and perform control to decrease a power of the radio resources. However, the method in which synchronization between base stations is necessary, and the definition of the message between base stations that have not been standardized are methods that are possible with the same operator and it is difficult to apply the methods to base stations between different operators.

As already described, it is necessary for the femtocell to limit the maximum transmission power of the femtocell in order to suppress interference with the base station using the adjacent frequency channel. In particular, a method of limiting the maximum transmission power of the femtocell when another operator is operating the adjacent frequency channel so that a radio wave of the femtocell does not give interference to a terminal of the other operator who uses the adjacent channel to prevent service of the other operator from being obstructed has been standardized.

For example, a standard of a radio characteristic of a base station of a UMTS scheme is shown in the 3GPP TS 25.104. In the 3GPP TS 25.104, a maximum transmission power of a femtocell (Home Base Station) of the UMTS scheme is defined as +20 dBm. However, it sets a limit on the maximum transmission power of the femtocell of the adjacent channel CPICH Êc+100 dB when a radio wave of −105 dBm (a threshold for limiting the maximum transmission power) or more of the adjacent frequency channel of the other operator is observed in the vicinity of the femtocell. This offset of 100 dB is a sum of an adjacent channel rejection ratio 33 dB, 47 dB of a femtocell area (path loss) to protect an adjacent channel macrocell terminal, −18 dB of a signal-to-noise power ratio (CPICH Ec/No) necessary for a terminal, and 2 dB of a set error. In fact, 98 dB, excluding the set error, may be set as the offset. Here, the reception power measurement value CPICH Êc of the adjacent channel pilot channel indicates a measurement value by the femtocell, and the measurement value by the femtocell is treated as the measurement value of the terminal since a small service area of the femtocell is included in a wide area of the macrocell as shown in FIG. **4**, and a distance between the femtocell and the terminal is smaller than a distance between the macrocell and the femtocell.

If a path loss between the adjacent channel macrocell and the femtocell is the same as a path loss between the adjacent channel macrocell and both terminals (a macrocell terminal and an adjacent channel macrocell terminal), a reception power (CPICH Ec) of the pilot channel of the adjacent channel measured by the femtocell and a power of the pilot channel of the adjacent channel received by the adjacent channel macrocell terminal may be considered to be the same. When the transmission power (HNBTxPo) of the femtocell is set to CPICH Ec+98 dB, a signal-to-noise ratio (adjMUE_CPICH_Ec/No) of the adjacent channel macrocell terminal present in a position with the path loss 47 dB from the femtocell is:

$$\begin{aligned}\text{adjMUE_CPICH_Ec/}No &= CPICH\ Ec-(HNBTxPo-47-33)\\ &= CPICH\ Ec-(CPICH\ Ec+98-47-33)\\ &= -18\ [\text{dB}]\end{aligned}$$

since the adjacent channel rejection ratio is 33 dB. Accordingly, −18 dB of the signal-to-noise ratio necessary for reception is secured.

Further, in addition to the above condition, when Ioh>CPICH Êc+43 dB, where Ioh denotes a total reception power (excluding the transmission power of the femtocell) in a frequency band used by the femtocell for a downlink, a limit of +10 dBm on the maximum transmission power is also set.

With the method in which the femtocell measures the intensity of the radio wave of the adjacent frequency channel and adds a certain offset to a reception power for the radio wave to determine the maximum transmission power of the femtocell, it is possible to protect an adjacent frequency channel macrocell terminal. However, for example, when the adjacent frequency channel femtocell is installed in the vicinity of the femtocell, communication quality of a terminal in the femtocell is degraded by unnecessarily limiting the power of the femtocell.

For example, a case in which the femtocell and the adjacent frequency channel femtocell are installed in positions with

path losses of 100 dB from the macrocell and 140 dB from an adjacent frequency channel macrocell, respectively, as shown in FIG. **5**, is considered. The transmission power of the adjacent frequency channel femtocell is set to −10 dBm through the transmission power control of FIG. **2**. In a method of related art in which a fixed offset is added to a measurement value for an adjacent frequency channel CPICH femtocell to determine a maximum transmission power of a femtocell, CPICH Ec/No of a terminal in a position with a path loss of 80 dB from each femtocell becomes as shown in FIG. **6** according to a path loss between the two femtocells. When the path loss between the two femtocells is 80 dB that is the same as a service area of the femtocell, it is difficult for the femtocell terminal to perform communication due to a degraded signal-to-noise ratio.

Thus, in the method of adding a certain offset to the reception power measurement value of the adjacent frequency channel measured by the femtocell to determine the maximum transmission power of the femtocell, the power of the femtocell is unnecessarily limited. Accordingly, the communication quality of the femtocell terminal may be degraded.

Further, since the femtocell is installed by a user, it is difficult for the operator to recognize, for example, an operation start time. Accordingly, it is necessary for the femtocell to have a function of autonomously setting radio parameters such as an optimal maximum transmission power. However, if the femtocell has a specification in which the setting of the transmission power is greatly affected each time an adjacent femtocell starts up, it is necessary for the femtocell to frequently measure a power of the peripheral femtocell and set its own transmission power again. Accordingly, the setting of the transmission power is not stable and the communication quality is degraded in an area in which femtocells are dense.

The present disclosure has been made in view of such a background, and the measurement of the radio wave intensity of the adjacent frequency channel and the acquisition of the base station type information by report information channel reception are simultaneously performed, the results of measuring adjacent frequency channels are classified for each base station type, and an offset or a calculation method appropriate for each base station type is used. Using such a method, it is possible to set an appropriate maximum transmission power of the femtocell.

The related art and its problems and the characteristics of the present disclosure have been described above. Next, an overall configuration of a data communication system according to an embodiment of the present disclosure will be described.

2. Embodiment of Present Disclosure

2-1. Overall Configuration of Data Communication System

FIG. **7** is an illustrative diagram showing an overall configuration of a data communication system according to an embodiment of the present disclosure. Hereinafter, the overall configuration of a data communication system according to an embodiment of the present disclosure will be described with reference to FIG. **7**.

A data communication system **1** shown in FIG. **7** is a data communication system including a femtocell. As shown in FIG. **7**, the data communication system **1** according to an embodiment of the present disclosure includes data communication terminals **10***a* and **10***b*, femtocells (indoor small base stations) **20***a* and **20***b*, the Internet **31**, femtocell gateways **32***a* and **32***b*, core networks **33***a* and **33***b*, BB line modems **34***a* and **34***b*, macrocells (outdoor base stations) **35***a* and **35***b*, and a femtocell management server **40***a*.

The macrocells (the outdoor base stations) **35***a* and **35***b* are base stations that cover a relatively wide range and have a cell radius of hundreds of m to tens of km. The femtocells (the indoor small base stations) **20***a* and **20***b* are base stations whose cell radius is tens of m and whose transmission power is small. The femtocells **20***a* and **20***b* may be installed and used at indoor places that are difficult for a radio wave of the macrocell to reach. The femtocells **20***a* and **20***b*, for example, are connected to the core networks **33***a* and **33***b* via the BB line modems **34***a* and **34***b*, BB lines, the Internet **31**, and the femtocell gateways **32***a* and **32***b*, respectively.

Communication interfaces between the femtocells **20***a* and **20***b* and the femtocell gateways **32***a* and **32***b* are defined as, for example, standard interfaces of Iuh (3GPP TS 25.467).

The femtocells **20***a* and **20***b* include wireless communication units **24***a* and **24***b* for performing wireless communication with the data communication terminals **10***a* and **10***b*, IP communication units **25***a* and **25***b* for performing wired communication with the femtocell management server **40***a* or the femtocell gateways **32***a* and **32***b*, control units **22***a* and **22***b* for performing control of frequency switching of the wireless communication units for measurement of a downlink radio wave of a peripheral base station, pilot channel measurement control, and the like, and storage units **26***a* and **26***b* for storing an address of the femtocell management server **40***a*, addresses of the femtocell gateways **32***a* and **32***b*, IDs of terminals whose positions can be registered in the femtocells **20***a* and **20***b*, and the like, respectively. Further, radio parameters of the femtocells **20***a* and **20***b*, a threshold for maximum transmission power control, and an offset value are also stored in the storage units **26***a* and **26***b*.

The femtocell management server **40***a* is a server for performing launch preparation, maintenance or the like of a femtocell treated by one business, and includes an IP communication unit **42***a* for performing communication with the plurality of femtocells **20***a* and **20***b*, and a storage unit **41***a*. An identification number, a carrier frequency, a scrambling code, position information and the like used by the femtocell managed by the femtocell management server **40***a* are stored in the storage unit **41***a*. In FIG. **7**, only one femtocell management server **40***a* operated by any business (e.g., referred to as a business A) is shown, but other businesses also operate such servers. Further, in the present disclosure, femtocells managed by a plurality of businesses may be managed by one femtocell management server.

If the femtocell **20***a* connected to the core network **33***a* of the business A is powered on, the femtocell **20***a* searches for a radio wave of a peripheral base station, measures a reception power of the base station, and receives and obtains report information of the base station. Further, the femtocell **20***a* is connected to the femtocell management server **40***a*, obtains information of a base station near a position indicated by position information registered in the femtocell management server **40***a*, compares the information with a measurement result of the femtocell **20***a* to confirm the position of the peripheral base station, and selects an optimal radio parameter not to overlap a radio parameter used by the peripheral base station.

The data communication terminal **10***a* and the data communication terminal **10***c* are terminals making a contract with the business A operating the core network **33***a*, and the data communication terminal **10***b* is a terminal making a contract with a business B operating the core network **33***b*. The femtocell **20***a* operated by the business A is connected to the core network **33***a* via the femtocell gateway **32***a*, and the femtocell

20*b* operated by the business B is connected to the core network 33*b* via the femtocell gateway 32*b*. Similarly, the macrocell 35*a* is a macrocell operated by the business A, and the macrocell 35*b* is a macrocell operated by the business B. The business A operates a downlink carrier frequency A, and the macrocell 35*a* and the femtocell 20*a* transmit the carrier frequency A in a downlink. The business B operates a downlink carrier frequency B, and the macrocell 35*b* and the femtocell 20*b* transmit the carrier frequency B in a downlink.

The overall configuration of a data communication system according to an embodiment of the present disclosure has been described above with reference to FIG. 7. Next, a configuration of the control unit 22*a* included in the femtocell 20*a* according to an embodiment of the present disclosure will be described.

FIG. 8 is an illustrative diagram showing a configuration of the control unit 22*a* included in the femtocell 20*a* according to an embodiment of the present disclosure. Hereinafter, the configuration of the control unit 22*a* included in the femtocell 20*a* according to an embodiment of the present disclosure will be described with reference to FIG. 8.

As shown in FIG. 8, the control unit 22*a* includes a power measurement unit 51*a*, a report information acquisition unit 52*a*, and a power setting unit 53*a*.

The power measurement unit 51*a* measures a power of a reference signal for synchronization at a downlink adjacent frequency. The power measurement unit 51*a* may not only measure the power of the reference signal for synchronization at the downlink adjacent frequency, but may also acquire report information, which is transmitted via a physical channel on the downlink.

The report information acquisition unit 52*a* acquires the report information. In the present embodiment, the report information acquisition unit 52*a* acquires a type of a base station that transmits a signal at the downlink adjacent frequency, contained in the report information. Accordingly, the report information acquisition unit 52*a* corresponds to a base station type acquisition unit of the present disclosure. Further, a method of acquiring the type of the base station in the report information acquisition unit 52*a* will be described later.

The power setting unit 53*a* sets the maximum transmission power of the femtocell 20*a* based on a measurement value of the power measured by the power measurement unit 51*a* and the type of the base station acquired by the report information acquisition unit 52*a*. The power setting unit 53*a* works without degrading communication quality of the terminal serviced from the femtocell 20*a* by setting the maximum transmission power of the femtocell 20*a* based on the measurement value of the power measured by the power measurement unit 51*a* and the type of the base station acquired by the report information acquisition unit 52*a*.

The configuration of the control unit 22*a* included in the femtocell 20*a* according to an embodiment of the present disclosure has been described above with reference to FIG. 8. Further, the control unit 22*a* may have the functional configuration as shown in FIG. 8, for example, by the control unit 22*a* reading and executing a computer program stored in the storage unit 26*a*.

The data communication terminal 10*a* and the data communication terminal 10*b* are at indoor places at which they can use the femtocells 20*a* and 20*b*. Meanwhile, the other data communication terminal 10*c* performs communication via the macrocell 35*a*. Since the data communication terminal 10*a* and the data communication terminal 10*b* are in a good radio wave communication environment with the femtocells 20*a* and 20*b* present at very close places, high throughput communication is possible. However, since the data communication terminal 10*c* is in communication with the distant macrocell 35*a*, a radio wave situation is bad. Also, since the data communication terminal 10*c* shares radio resources with other terminals, which share the same macrocell 35*a*, it is difficult to expect sufficient throughput.

If the data communication terminal 10*c* is close to the femtocell 20*b*, a downlink signal transmitted by the femtocell 20*b* is a noise for the data communication terminal 10*c*. Accordingly, when the transmission power of the femtocell 20*b* is greater, reception quality of the data communication terminal 10*c* is degraded. Conversely, if the transmission power of the femtocell 20*b* is too small, the reception quality of the data communication terminal 10*b* is degraded.

The embodiment of the present disclosure is intended to improve communication quality of the overall data communication system using the method of setting the transmission power of the femtocell, which moderately maintains reception qualities of both the femtocell terminal and the macrocell terminal. Hereinafter, the method of setting the transmission power of the femtocell will be described by way of concrete example.

2-2. Method using Another Calculation Method when Adjacent Channel is for Femtocell

As a first method, a method of setting a transmission power of the femtocell 20*a* or 20*b* a method using another calculation method when an adjacent channel is for a femtocell will be described.

When an adjacent frequency channel macrocell is in a range of a protection condition (−105 dBm≤CPICH Ec in the UMTS scheme), that is, when a pilot channel reception power of the adjacent frequency channel macrocell exceeds a predetermined threshold (−105 dBm), the femtocell 20*a* or 20*b* adds an existing offset value (98 dB in the UMTS scheme) to the pilot channel reception power of the adjacent frequency channel macrocell to determine the maximum transmission power of the femtocell 20*a* or 20*b*. However, when a radio wave intensity of the adjacent frequency channel by the adjacent frequency channel femtocell is dominant, the femtocell 20*a* or 20*b* adds, for example, an offset value for the femtocell (e.g., 51 dB in the UMTS scheme) to the pilot channel transmission power of the adjacent frequency channel femtocell to determine the maximum transmission power of the femtocell 20*a* or 20*b*.

The offset value for the femtocell, 51 dB, is a sum of the adjacent channel rejection ratio 33 dB and a signal-to-noise ratio (CPICH Ec/No) −18 dB required at the end.

This is intended to protect reception quality of an adjacent channel femtocell terminal present at a middle point between the femtocell and the adjacent channel femtocell. That is, as shown in FIG. 10, a path loss between the adjacent channel femtocell and the adjacent channel femtocell terminal (adjHUE) is the same as a path loss between the femtocell and a femtocell terminal (HUE). In this method, a fixed offset value is only added to the pilot channel transmission power of the adjacent frequency channel femtocell and, accordingly, the path loss from the femtocell to the terminal may not be considered.

A value of the pilot channel transmission power of the adjacent frequency channel femtocell may be obtained by the femtocell receiving the report information of the adjacent frequency channel femtocell.

When (CPICH_Po+51) dB obtained by adding an offset 51 dB to the pilot channel transmission power (CPICH_Po) of the adjacent frequency channel is set as the transmission power (HNBTxPo) of the femtocell, a signal-to-noise ratio

(adjHUE_CPICH_Ec/No) of the adjacent channel femtocell terminal present at the middle point between the femtocell and the adjacent frequency channel femtocell is:

$$\begin{aligned} \text{adjHUE_CPICH_Ec/}No &= \text{CPICH_Po-}PLHNBadj+x\text{-}(HNBTxPo-PLHNBadj+x\text{-}33) \\ &= \text{CPICH_Po-}PLHNBadj+x\text{-}(\text{CPICH_Po}+51-PLHNBadj+x\text{-}33) \\ &= -18\ [\text{dB}] \end{aligned}$$

since the adjacent channel rejection ratio is 33 dB. Accordingly, −18 dB of a signal-to-noise ratio necessary for reception is secured.

FIGS. **9**A and **9**B are flowcharts showing an operation of the control unit **22***a* of the femtocell **20***a* according to an embodiment of the present disclosure. The flowcharts shown in FIGS. **9**A and **9**B show an operation of the control unit **22***a* when the control unit **22***a* executes transmission power control. Hereinafter, an operation of the control unit **22***a* of the femtocell **20***a* according to an embodiment of the present disclosure will be described with reference to FIGS. **9**A and **9**B.

The control unit **22***a* measures a reception power (Ioh) of its own channel using the power measurement unit **51***a* (step S**61**). As the power measurement unit **51***a* measures the reception power (Ioh) of its own channel, a threshold (a second threshold), which will be described later, is set.

If the control unit **22***a* measures the reception power (Ioh) of its own channel using the power measurement unit **51***a* in step S**61**, the control unit **22***a* sets a carrier frequency of the wireless communication unit **24***a* to an adjacent channel frequency and measures a reception power (step S**62**).

The control unit **22***a* determines whether any adjacent channel adjacent to the carrier frequency set in step S**62** is being used (step S**63**). If it is determined in step S**63** that no adjacent channel is being used, the process ends directly. On the other hand, if it is determined in step S**63** that an adjacent channel is being used, the report information acquisition unit **52***a* receives report information from a reception signal of the adjacent channel received by the wireless communication unit **24***a* (step S**64**). An operator identification number of the base station, a maximum transmission power, a pilot channel transmission power, a base station identification number, a femtocell identification number, ABS information, RNTP information, and the like are contained in the report information.

If the report information acquisition unit **52***a* receives the report information in step S**64**, the power measurement unit **51***a* measures a reception power of the reference signal for synchronization (a pilot channel) in the adjacent channel (step S**65**). If the power measurement unit **51***a* measures the reception power of the reference signal for synchronization in the adjacent channel in step S**65**, the control unit **22***a* determines whether the adjacent channel is for the other business (step S**66**).

If it is determined in step S**66** that the adjacent channel is not for the other business, the process ends directly. On the other hand, if it is determined in step S**66** that the adjacent channel is for the other business, the control unit **22***a* determines whether the adjacent channel is for a femtocell (step S**67**). The determination as to whether the adjacent channel is for a femtocell is made by referencing the base station type information contained in the report information received by the report information acquisition unit **52***a*.

A process when it is determined in step S**67** that the adjacent channel is for a femtocell will be described. If it is determined in step S**67** that the adjacent channel is for a femtocell, the control unit **22***a* determines whether the pilot channel reception power measured by the power measurement unit **51***a* is equal to or more than a first threshold (step S**68**). If it is determined in step S**68** that the pilot channel reception power measured by the power measurement unit **51***a* is less than the first threshold, the process ends directly. On the other hand, if it is determined in step S**68** that the pilot channel reception power measured by the power measurement unit **51***a* is equal to or more than the first threshold, the control unit **22***a* determines whether the pilot channel reception power measured by the power measurement unit **51***a* is equal to or more than a second threshold (step S**69**).

If it is determined in step S**69** that the pilot channel reception power measured by the power measurement unit **51***a* is less than the second threshold, the power setting unit **53***a* sets the maximum transmission power to a predetermined value (e.g., 10 dBm) (step S**70**). On the other hand, if it is determined in step S**69** that the pilot channel reception power measured by the power measurement unit **51***a* is equal to or more than the second threshold, the power setting unit **53***a* sets the maximum transmission power to a pilot channel transmission power plus a predetermined offset (step S**71**).

If the power setting unit **53***a* sets the maximum transmission power to a pilot channel transmission power plus a predetermined offset in step S**71**, the power setting unit **53***a* determines whether the new maximum transmission power is smaller than a previous maximum transmission power (step S**72**).

If it is determined in step S**72** that the new maximum transmission power is smaller than the previous maximum transmission power, the power setting unit **53***a* updates the maximum transmission power to a set value (step S**73**), and the process ends. On the other hand, if it is determined in step S**72** that the new maximum transmission power is not smaller than the previous maximum transmission power, the process ends directly without doing anything.

Next, a process when it is determined in step S**67** that the adjacent channel is not for a femtocell (is for a macrocell) will be described. If it is determined in step S**67** that the adjacent channel is not for a femtocell, the control unit **22***a* determines whether the pilot channel reception power measured by the power measurement unit **51***a* is equal to or more than the first threshold (step S**74**). If it is determined in step S**74** that the pilot channel reception power measured by the power measurement unit **51***a* is less than the first threshold, the process ends directly. On the other hand, if it is determined in step S**74** that the pilot channel reception power measured by the power measurement unit **51***a* is equal to or more than the first threshold, the control unit **22***a* determines whether the pilot channel reception power measured by the power measurement unit **51***a* is equal to or more than the second threshold (step S**75**).

If it is determined in step S**75** that the pilot channel reception power measured by the power measurement unit **51***a* is less than the second threshold, the power setting unit **53***a* sets the maximum transmission power to a predetermined value

(e.g., 10 dBm) (step S76). On the other hand, if it is determined in step S75 that the pilot channel reception power measured by the power measurement unit **51***a* is equal to or more than the second threshold, the power setting unit **53***a* sets the maximum transmission power to a pilot channel reception power plus a predetermined offset (step S77).

If the power setting unit **53***a* sets the maximum transmission power to a pilot channel reception power plus a predetermined offset in step S77, the power setting unit **53***a* determines whether the new maximum transmission power is smaller than the previous maximum transmission power (step S72).

If it is determined in step S72 that the new maximum transmission power is smaller than the previous maximum transmission power, the power setting unit **53***a* updates the maximum transmission power to the set value (step S73) and the process ends. On the other hand, if it is determined in step S72 that the new maximum transmission power is not smaller than the previous maximum transmission power, the process ends directly without doing anything.

The operation of the control unit **22***a* of the femtocell **20***a* according to an embodiment of the present disclosure has been described above with reference to FIGS. **9**A and **9**B. As described above, when the adjacent channel is for the femtocell, the transmission power of the femtocell **20***a* or **20***b* is set using a different calculation method from the case of the macrocell, thereby improving communication quality of the overall data communication system.

2-3. Method of Excluding Power from Adjacent Femtocell

As a second method, a method of setting the transmission power of the femtocell using a method of excluding power from an adjacent femtocell will be described.

When there are limits on the maximum transmission power of a wireless station, a minimum value among a plurality of maximum transmission powers is adopted. As shown previously, in the 3GPP TS 25.104 that is a standard of a radio characteristic of a base station of a UMTS scheme, the maximum transmission power of the femtocell is defined as +20 dBm. Accordingly, when a power ratio of the pilot channel to a total transmission power of the femtocell is, for example, −10 dB and a minimum transmission power of the femtocell is, for example, −10 dBm, (CPICH_Po+51) dB becomes +31 dBm. However, in fact, the maximum transmission power is limited to the upper limit of +20 dBm.

Accordingly, in this case, when the radio wave intensity of the adjacent frequency channel by the adjacent frequency channel femtocell is dominant as a result of classifying the results of measuring the adjacent frequency channel in the femtocell **20***a* or **20***b* for each base station type, the femtocell **20***a* or **20***b* may not use a radio wave intensity of the adjacent frequency channel by the adjacent frequency channel femtocell to calculate the maximum transmission power.

FIG. **11** shows a calculation example of CPICH Ec/No of a macrocell terminal (MUE), a femtocell terminal (HUE), and an adjacent channel femtocell terminal (adjHUE) when a path loss (PLHNBadj) between an adjacent channel femtocell and a femtocell is changed. A macrocell, a femtocell, an adjacent channel macrocell, and an adjacent channel femtocell are arranged as shown in FIG. **5**, and a radio wave intensity of the adjacent frequency channel femtocell is dominant in the adjacent frequency channel. When PLHNBadj is equal to or less than 90 dB, the radio wave intensity of the adjacent frequency channel is more than −105 dBm. Accordingly, in a scheme of related art, the maximum transmission power of the femtocell is limited. However, in the calculation example shown in FIG. **11**, the radio wave intensity of the adjacent frequency channel is treated as noise and only added to a value of No of CPICH Ec/No of each terminal. Further, when PLHNBadj is equal to or more than 70 dB, a signal-to-noise ratio necessary for reception is satisfied in all the terminals, and the above-described problem as shown in FIG. **6** is resolved by this method, as can be confirmed.

As described above, when the adjacent channel is a femtocell, the transmission power of the femtocell **20***a* or **20***b* is set using the method of excluding a power from the adjacent femtocell, thereby improving communication quality of the overall data communication system.

2-4. Method of Setting Threshold and Offset Value According to Base Station Type

As a third method, a method of setting a transmission power of a femtocell using a method of setting a threshold and an offset value according to a base station type will be described.

In a method of related art, two thresholds are set for a pilot channel reception power to protect a macrocell of an adjacent frequency channel. For example, in the case of a UMTS scheme, a determination is made as to whether the pilot channel reception power is equal to or more than −105 dBm (a first threshold) or is equal to or more than a reception power in a downlink frequency band of the femtocell Ioh-43 dB (a second threshold) to determine the maximum transmission power. When the adjacent frequency channel is the femtocell, for example, −70 dBm obtained by subtracting a coverage 80 dB from a pilot channel transmission power 10 dBm may be used as the first threshold.

The method of setting the transmission power of the femtocell may be a method of setting the value according to the base station type as the threshold and the offset value of the reception power of the reference signal for synchronization for determination as to whether to limit the maximum transmission power, as described above, that is, a method of setting a different threshold and a different offset value according to whether the base station is a macrocell or a femtocell.

Here, the measurement of the power of the adjacent frequency channel by the femtocell **20***a* or **20***b* will be described. The measurement of the power of the adjacent frequency channel by the femtocell **20***a* or **20***b* is realized, for example, by changing a setting of the frequency synthesizer of the wireless communication unit **24***a* or **24***b* of the femtocell **20***a* or **20***b* using the control unit **22***a* or **22***b*, temporarily changing the reception frequency to the adjacent frequency channel, and measuring the reception power using the control unit **22***a* or **22***b* at a time when the femtocell **20***a* or **20***b* is powered on or reset, during a period of time in which there is no terminal making communication using the femtocell **20***a* or **20***b*, or the like.

FIG. **12** is an illustrative diagram showing a configuration example of the wireless communication unit **24***a* in the femtocell **20***a* according to an embodiment of the present disclosure. As shown in FIG. **12**, the wireless communication unit **24***a* includes an antenna **101**, a duplexer **102**, a reception processing unit **110**, a transmission processing unit **120**, a baseband processing unit **130**, a bias control unit **140**, a crystal oscillator **150**, and a frequency synthesizer **160**.

The reception processing unit **110** includes a reception amplifier **111**, a reception RF filter **112**, and a quadrature demodulator **113**. Also, the transmission processing unit **120** includes a quadrature modulator **121**, a transmission variable-

gain amplifier **122**, a transmission RF filter **123**, a transmission power amplifier **124**, and an isolator **125**.

A signal received by the antenna **101** is sent to the reception processing unit **110** via the duplexer **102**. The reception processing unit **110** amplifies the signal received from the duplexer **102** using the reception amplifier **111**, executes predetermined filtering using the reception RF filter **112**, and demodulates the signal using the quadrature demodulator **113**. The demodulated signal is sent to the baseband processing unit **130**.

Further, a signal sent from the baseband processing unit **130** to the transmission processing unit **120** is modulated by the quadrature modulator **121**, amplified by the transmission variable-gain amplifier **122**, subjected to predetermined filtering in the transmission RF filter **123**, amplified by the transmission power amplifier **124**, and sent to the duplexer **102** via the isolator **125** that prevents backflow of a signal. Also, the signal sent to the duplexer **102** is transmitted from the antenna **101**.

The bias control unit **140** controls bias for the reception processing unit **110** and the transmission processing unit **120**. Further, the frequency synthesizer **160** receives a clock from the crystal oscillator **150** to generate a high frequency clock at a predetermined frequency. The generated clock is supplied to the quadrature demodulator **113** and the quadrature modulator **121** and used for demodulation and modulation.

The measurement of the power of the adjacent frequency channel by the femtocell **20***a* is realized by changing a setting of the frequency synthesizer **160** of the wireless communication unit **24***a* using the control unit **22***a*, temporarily changing a reception frequency to the adjacent frequency channel, and measuring the reception power using the control unit **22***a*.

In a UMTS scheme, powers of pilot channels of a plurality of base stations can be divided and measured by de-spreading a received baseband signal in a scrambling code of the pilot channel that can be allocated to each base station.

Further, in the LTE scheme, as shown in FIG. **13**, positions of a sub-carrier and a symbol in which a reference signal (CRS) is arranged in each subframe are determined according to the identification number of the base station, and phase rotation is assigned to the reference signal according to the identification number of the base station. The power of the adjacent frequency channel can be measured by measuring intensities of the reference signals and dividing powers of the reference signals of a plurality of base stations.

When the power of the reference signal of the base station is measured, for example, variable factors due to a change in the radio environment can be absorbed by performing multiple measurements on a plurality of radio frames and averaging the measured values.

However, in versions subsequent to Release 10 of the LTE scheme, there is likely to be an Almost Blank Subframe (ABS) that is a subframe containing no reference signal. Because of this, when a position of radio resources in which a reference signal to be measured by the femtocell is arranged is determined based on only the identification number of the base station, an error may be generated.

For example, the femtocell **20***a* or **20***b* receives report information of the adjacent frequency channel base station, obtains information (ABS information) on a number of the subframe containing no reference signal, and excludes the subframe containing no reference signal from a measurement target to perform measurement. Thus, as the measurement is performed while excluding the subframe containing no reference signal from the measurement target, the femtocell **20***a* or **20***b* can perform the power measurement with higher accuracy.

As important system information is transmitted in first to sixth subframes, the ABS is not set but the reference signal is transmitted in the sixth subframe in each base station, and another base station that has shifted the subframe in time is caused to use the ABS, such that the important system information can be protected from interference. When the femtocell **20***a* or **20***b* measures the reference signal of the peripheral base station, the femtocell measures only a subframe having a specific number that is known to contain the reference signal in advance and have less interference from other base stations, such as only the sixth subframe of the base station as a measurement target. Accordingly, the femtocell **20***a* or **20***b* can perform highly accurate power measurement.

Further, in the LTE scheme, as shown in FIG. **14**, in order to reduce interference of a terminal at a cell edge, a frequency band operated by the base station is divided into frequency blocks and a transmission power for each frequency block is changed. Also, in the LTE scheme, the frequency block with a high transmission power can be allocated to the terminal at the cell edge and the frequency block with a low transmission power can be allocated to a terminal at a cell center. For example, the femtocell **20***a* or **20***b* performs power measurement of the reference signal of the adjacent frequency channel base station, receives the report information, obtains transmission power information (RNTP information) for each frequency block, and calculates a path loss from the adjacent frequency channel base station to the femtocell. The femtocell **20***a* or **20***b* can perform highly accurate power measurement by measuring only the reference signal of the frequency block that can be allocated to a place of the femtocell **20***a* or **20***b*.

Next, a method of analyzing a base station type based on report information channel reception will be described. A report information channel of the base station is a channel used to transmit system information from a network to all terminals in coverage of the base station. The report information channel may be received by only a downlink reception function of the femtocell **20***a* or **20***b*. This report information contains an operator identification number of the base station, a maximum transmission power, a pilot channel transmission power, a base station identification number, a femtocell identification number, ABS information, RNTP information, and the like. For example, when the femtocell **20***a* or **20***b* performs the measurement of the power of the adjacent frequency channel, the femtocell **20***a* or **20***b* also performs report information channel reception and can determine whether the adjacent frequency channel base station is a femtocell or not based on whether the femtocell identification number is a significant number.

2-5. Method of Setting a Plurality of Maximum Transmission Power Candidates

As a fourth method, a method of setting a transmission power of a femtocell using a method of setting a plurality of maximum transmission power candidates will be described.

In order to set a plurality of maximum transmission power candidates, for example, when a plurality of pilot channels are detected at downlink adjacent frequencies, the femtocell **20***a* or **20***b* may calculate a maximum transmission power for each base station type and adopt a minimum value among the maximum transmission powers as the maximum transmission power of the femtocell.

The femtocell **20***a* or **20***b* obtains a limit on a femtocell maximum transmission power for an individual base station by associating a base station identification number, a base station type (whether the base station is a femtocell or not),

and a pilot channel reception power of the adjacent frequency channel. Also, the femtocell **20***a* or **20***b* adopts the most severe value among such limits (the smallest value of the maximum transmission powers) and sets the value as the maximum transmission power of the femtocell **20***a* or **20***b*.

For a plurality of base stations that have measured the pilot channel of the adjacent frequency channel base station, the femtocell **20***a* or **20***b* individually calculates the femtocell maximum transmission power using the following equation:

$$[\text{femtocell maximum transmission power}]=[\text{adjacent channel base station pilot channel reception power}]+[\text{offset value}] \quad (1)$$

A method in which, when the adjacent frequency channel base station is, for example, a macrocell of a UMTS scheme, the femtocell **20***a* or **20***b* uses 98 dB as the offset value in Equation (1) and when the adjacent frequency channel base station is a femtocell, the femtocell **20***a* or **20***b* uses an infinite value as the offset value in Equation (1) to remove the limit on the femtocell may be used.

A method in which, when the adjacent frequency channel base station is, for example, a macrocell of a UMTS scheme, the femtocell **20***a* or **20***b* uses 98 dB as the offset value in Equation (1), and when the adjacent frequency channel base station is a femtocell, the femtocell uses a value of 51 dB as an offset value in the following equation (2) not to consider the path loss as a limit on the femtocell may also be used.

$$[\text{femtocell maximum transmission power}]=[\text{adjacent channel base station pilot channel transmission power}]+[\text{offset value}] \quad (2)$$

Thus, using the method of assigning the offset value or the calculation equation to each type of the adjacent frequency channel base station, the femtocell **20***a* or **20***b* individually calculates the limit on the maximum transmission power of the femtocell and adopts a minimum value among the maximum transmission powers. As described above, the femtocell **20***a* or **20***b* sets the transmission power of the femtocell **20***a* or **20***b* using the method of setting a plurality of maximum transmission power candidates, thereby improving the communication quality of the overall data communication system.

3. Conclusion

As described above, according to the embodiment of the present disclosure, in the method in which the base station measures a downlink reception power of an adjacent frequency channel base station and the measured reception power plus the offset value is determined as the maximum transmission power of the base station, the offset value or the threshold according to the base station type of the adjacent frequency channel base station is used. As the maximum transmission power of the base station is set as described above, it is possible, in the embodiment of the present disclosure, to provide a wireless base station and a transmission power control method capable of protecting a service area of the adjacent frequency channel base station and autonomously setting the maximum transmission power of the base station without unnecessarily limiting the service area of the base station.

Further, according to the embodiment of the present disclosure, if there is a femtocell base station of an adjacent frequency channel operated by another operator when a femtocell base station starts up, the femtocell can autonomously set its own maximum transmission power to protect a service area of the adjacent frequency channel femtocell base station while maintaining the service area of the femtocell base station.

Further, according to the embodiment of the present disclosure, setting a fair maximum transmission power to protect a terminal located in the middle of two femtocells can be simply autonomously realized. Furthermore, according to the embodiment of the present disclosure, the transmission power control is not performed each time a femtocell starts up in the vicinity, thereby achieving a stable operation of an overall network.

Further, a series of control processes by each device described in this disclosure may be realized by any of software, hardware, and a combination of the software and the hardware. A program constituting the software is, for example, stored in a storage medium provided inside or outside each device in advance. Also, each program is, for example, loaded to a RAM when executed and then executed by a processor.

It should be understood by those skilled in the art that various modifications, combinations, sub-combinations and alterations may occur depending on design requirements and other factors insofar as they are within the scope of the appended claims or the equivalents thereof.

Additionally, the present technology may also be configured as below.

(1) A wireless base station comprising:

a power measurement unit for measuring a power of a reference signal for synchronization at a downlink adjacent frequency;

a base station type acquisition unit for acquiring a type of a base station that transmits the signal at the downlink adjacent frequency; and

a power setting unit for setting a maximum transmission power based on a measurement value of the power measured by the power measurement unit and the type of the base station acquired by the base station type acquisition unit.

(2) The wireless base station according to (1), wherein

the power setting unit has a first pattern in which a measurement value of a reception power of the reference signal for synchronization at the downlink adjacent frequency plus a first offset value is set as the maximum transmission power, and a second pattern in which a measurement value of a transmission power of the reference signal for synchronization at the downlink adjacent frequency plus a second offset value is set as the maximum transmission power, and selects the first pattern or the second pattern as a set pattern for the maximum transmission power according to the type of the base station acquired by the base station type acquisition unit.

(3) The wireless base station according to (2), wherein

in the first pattern, the power setting unit sets values according to the type of the base station acquired by the base station type acquisition unit as a threshold of the reception power of the reference signal for synchronization for determination as to whether to limit the maximum transmission power, and the first offset value.

(4) The wireless base station according to any one of (1) to (3), wherein

the power setting unit excludes a reception power of the reference signal for synchronization at the downlink adjacent frequency from a maximum transmission power calculation target when the type of the base station acquired by the base station type acquisition unit is a small base station.

(5) The wireless base station according to any one of (1) to (4), wherein

when the power measurement unit has detected a plurality of reference signals for synchronization at the downlink adja-

cent frequency, the base station type acquisition unit acquires the type of the base station for each reference signal for synchronization, and the power setting unit sets, as the maximum transmission power, a minimum value among a plurality of maximum transmission powers calculated from power measurement values of the plurality of reference signals for synchronization according to the type of the base station acquired by the base station type acquisition unit.

(6) The wireless base station according to any one of (1) to (5), wherein

the power measurement unit acquires information of a frame containing the reference signal for synchronization from report information, and measures a reception power of the reference signal for synchronization of the frame.

(7) The wireless base station according to any one of (1) to (7), wherein

the power measurement unit measures a reception power of the reference signal for synchronization only in a specific frame known to contain the reference signal for synchronization in advance.

(8) The wireless base station according to any one of (1) to (7), wherein

when an adjacent frequency channel base station divides a used downlink frequency band into a plurality of frequency blocks and changes transmission powers of the respective frequency blocks, the power measurement unit acquires information of a transmission power for each frequency block from report information and measures a reception power of the reference signal for synchronization of the frequency block.

(9) A transmission power control method comprising:

measuring a power of a reference signal for synchronization at a downlink adjacent frequency;

acquiring a type of a base station that transmits the signal at the downlink adjacent frequency; and

setting a maximum transmission power based on a measurement value of the power measured in the power measurement step and the type of the base station acquired in the base station type acquisition step.

(10) A computer program for causing a computer to execute:

measuring a power of a reference signal for synchronization at a downlink adjacent frequency;

acquiring a type of a base station that transmits the signal at the downlink adjacent frequency; and

setting a maximum transmission power based on a measurement value of the power measured in the power measurement step and the type of the base station acquired in the base station type acquisition step.

The present disclosure contains subject matter related to that disclosed in Japanese Priority Patent Application JP 2011-172927 filed in the Japan Patent Office on Aug. 8, 2011, the entire content of which is hereby incorporated by reference.

What is claimed is:

1. A wireless base station comprising:

a processor configured to:

measure a power of a reference signal for synchronization at a downlink adjacent frequency;

acquire a type of a base station that transmits the reference signal at the downlink adjacent frequency; and

set a maximum transmission power of the wireless base station based on a measurement value of the measured power of the reference signal and an offset value determined based on the acquired type of the base station, wherein the offset value is a sum of an adjacent channel rejection ratio and a predetermined signal-to-noise ratio when the acquired type of the base station is a first base station type, and wherein

a predetermined value of power is set as the maximum transmission power when the measurement value of the measured power of the reference signal is between a first threshold and a second threshold.

2. The wireless base station according to claim **1**, wherein

a first pattern in which a measurement value of a reception power of the reference signal for synchronization at the downlink adjacent frequency plus a first offset value is set as the maximum transmission power, and a second pattern in which a measurement value of a transmission power of the reference signal for synchronization at the downlink adjacent frequency plus a second offset value is set as the maximum transmission power, and the first pattern or the second pattern is selected as a set pattern, for the maximum transmission power according to the acquired type of the base station, when the measurement value of the measured power of the reference signal is equal to or more than the second threshold.

3. The wireless base station according to claim **2**, wherein

in the first pattern, values are set according to the acquired type of the base station as a threshold of the reception power of the reference signal for synchronization for determination as to whether to limit the maximum transmission power, and the first offset value.

4. The wireless base station according to claim **1**, wherein

the processor is further operable to exclude a reception power of the reference signal for synchronization at the downlink adjacent frequency from a maximum transmission power calculation target when the acquired type of the base station is a femtocell base station.

5. The wireless base station according to claim **1**, wherein

when a plurality of reference signals for synchronization at the downlink adjacent frequency are detected, the type of the base station for each reference signal for synchronization is acquired, and the maximum transmission power is set as a minimum value among a plurality of maximum transmission powers calculated from power measurement values of the plurality of reference signals for synchronization according to the acquired type of the base station.

6. The wireless base station according to claim **1**, wherein

the processor is further configured to acquire information of a frame containing the reference signal for synchronization from report information, and measure a reception power of the reference signal for synchronization of the frame.

7. The wireless base station according to claim **1**, wherein

the processor is further configured to measure a reception power of the reference signal for synchronization only in a specific frame known to contain the reference signal for synchronization in advance.

8. The wireless base station according to claim **1**, wherein

when an adjacent frequency channel base station divides a used downlink frequency band into a plurality of frequency blocks and changes transmission powers of the respective plurality of frequency blocks, information of a transmission power for each frequency block of the plurality of frequency blocks is acquired from report information and a reception power of the reference signal for synchronization of the frequency block is measured.

9. A method for controlling transmission power of a wireless base station, the method comprising:

measuring a power of a reference signal for synchronization at a downlink adjacent frequency;

acquiring a type of a base station that transmits the reference signal at the downlink adjacent frequency; and

setting a maximum transmission power of the wireless base station based on a measurement value of the measured power of the reference signal and an offset value determined based on the acquired type of the base station, wherein the offset value is a sum of an adjacent channel rejection ratio and a predetermined signal-to-noise ratio when the acquired type of the base station is a first base station type, and wherein

a predetermined value of power is set as the maximum transmission power when the measurement value of the measured power of the reference signal is between a first threshold and a second threshold, and

the measured power of the reference signal plus the determined offset value is set as the maximum transmission power when the measurement value of the measured power of the reference signal is equal to or more than the second threshold.

10. A non-transitory computer-readable medium, having stored thereon, a computer program having at least one code section executable by a computer, thereby causing the computer to perform the steps comprising:

measuring a power of a reference signal for synchronization at a downlink adjacent frequency;

acquiring a type of a base station that transmits the reference signal at the downlink adjacent frequency; and

setting a maximum transmission power of a wireless base station based on a measurement value of the measured power of the reference signal and an offset value determined based on the acquired type of the base station, wherein the offset value is a sum of an adjacent channel rejection ratio and a predetermined signal-to-noise ratio when the acquired type of the base station is a first base station type, and wherein

a predetermined value of power is set as the maximum transmission power when the measurement value of the measured power of the reference signal is between a first threshold and a second threshold, and

the measured power of the reference signal plus the determined offset value is set as the maximum transmission power when the measurement value of the measured power of the reference signal is equal to or more than the second threshold.

11. The wireless base station according to claim **1**, wherein the acquired type of the base station is one of a femtocell base station and a macrocell base station.

12. The wireless base station according to claim **1**, wherein the wireless base station is operated by a first operator and the acquired base station that transmits the reference signal is operated by a second operator.

13. The wireless base station according to claim **1**, wherein the measured power of the reference signal plus the determined offset value is set as the maximum transmission power when the measurement value of the measured power of the reference signal is equal to or more than the second threshold.

14. The wireless base station according to claim **1**, wherein the first base station type is a femtocell base station.

* * * * *